Oceanus

Volume 34, Number 2, Summer 1991

An Open Door: Soviet-American Cooperation

Vicky Cullen
Editor

Lisa Clark
Assistant Editor

Kathy Sharp Frisbee
Editorial Assistant

Robert W. Bragdon
Advertising & Business Coordinator

Allison Janse
Publishing Intern

Traci Watson
Publishing Intern

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Oceanus Magazine
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543,
or telephone: (508) 457-2000, extension 2386.

Subscribers within the US, please write: *Oceanus* Subscriber Service Center, P.O. Box 6419, Syracuse, NY 13217-6419. Individual subscription rate, $25 per year; Students, $20; Libraries and institutions, $50. Current issue price, $6.25; 25% discount on current issue orders for five or more. Please make checks payable to the Woods Hole Oceanographic Institution.

Subscribers outside the US, please write: *Oceanus*, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge CB2 2RU, England. Individual subscription rate: £24 per year; Students, £15; Libraries and Institutions, £43. Single-copy price, £7. Please make checks payable to Cambridge University Press.

Canadian subscriptions available through Faxon at P.O. Box 2382, London, Ontario N6A 5A7, Canada. Add $5 to basic rates.

When sending change of address, please include mailing label. Claims for missing numbers from the US will be honored within three months of publication; overseas, five months.

Oceanus

International Perspectives on Our Ocean Environment
Volume 34, Number 2, Summer 1991 ISSN 0029-8182

Published Quarterly by the Woods Hole Oceanographic Institution

Editorial Advisory Board

ISSN 0029-8182/83 $2.00 + .05. GST R 101 749 364.

SOVIET-AMERICAN COOPERATION

Emory Kristof © National Geographic Society

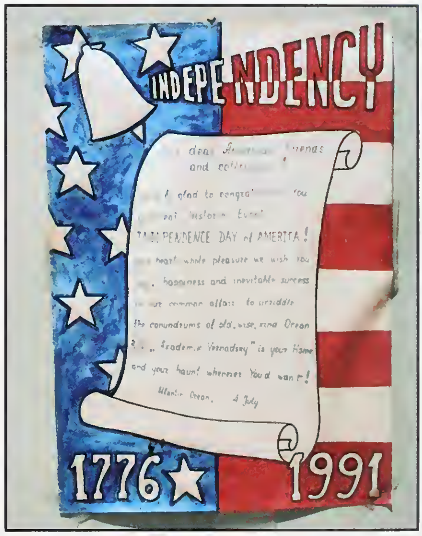
US Coast Guard

Skip Owen

 Oceanus (ISSN 0029-8182) is published in March, June, September, and December by the Woods Hole Oceanographic Institution, 9 Maury Lane, Woods Hole, Massachusetts 02543. Second-class postage paid at Falmouth, Massachusetts and additional mailing points.
POSTMASTER: Send address change to Oceanus Subscriber Service Center, P.O. Box 6419, Syracuse, NY 13217-6419.

Headings and Readings

Gary Bond



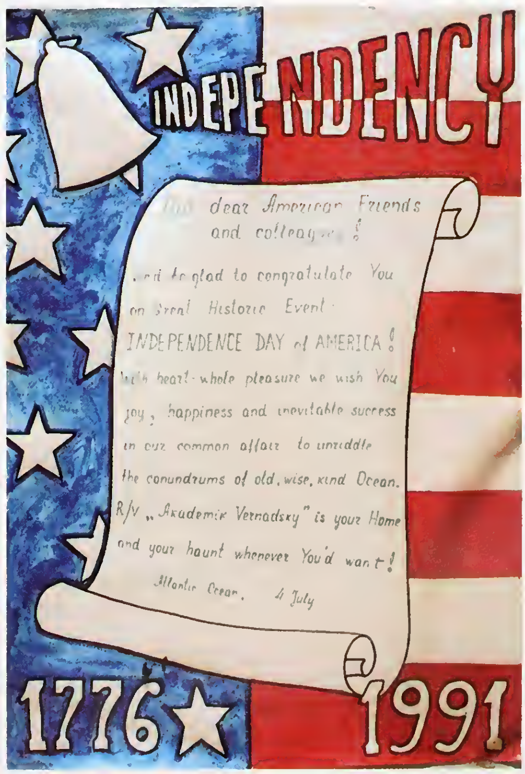
THE COVER: Photographer Lisa Poole captured this dramatic image of St. Basil's Cathedral in Red Square, Moscow, one cold January evening. Her visit was part of a journalism-photography field trip in 1988. Lisa will intern with *Oceanus* in the fall.

From the editor on

An Open Door: Soviet-American Cooperation in Marine Science

Following scientific and journalistic curiosity can lead to interesting adventures. This issue on the open door between scientists of very different political cultures offers our readers a glimpse of Soviet ocean issues and some warm, amusing views of the human side of scientific cooperation among Russians and Americans. In their article on Soviet oceanographic history, authors Brekovskikh and Neiman note that "a scientific result, as part of genuine understanding, belongs to the whole of mankind." This is the spirit of USSR-US cooperation and the theme for this issue.

Long-standing alliances between Soviet and Woods Hole Oceanographic Institution (WHOI) oceanographers were strengthened by Craig Dorman shortly after he became director in February 1989. He declared an institution initiative to encourage US-USSR collaboration, and kicked off the cooperative effort by inviting the 124-meter research vessel *Akademik Vernadsky* to call at the WHOI pier in June 1989. When the ship departed after two days of tours, picnicking, dancing, and reciprocal hospitality ashore and aboard ship, it carried Physical Oceanographer Nick Fofonoff, Research Assistant Ellen Levy, and Summer Student Fellows James Kettle and Richard Navitsky for cooperative studies of the energy exchange between the internal wave field and the general current field in the Gulf Stream.



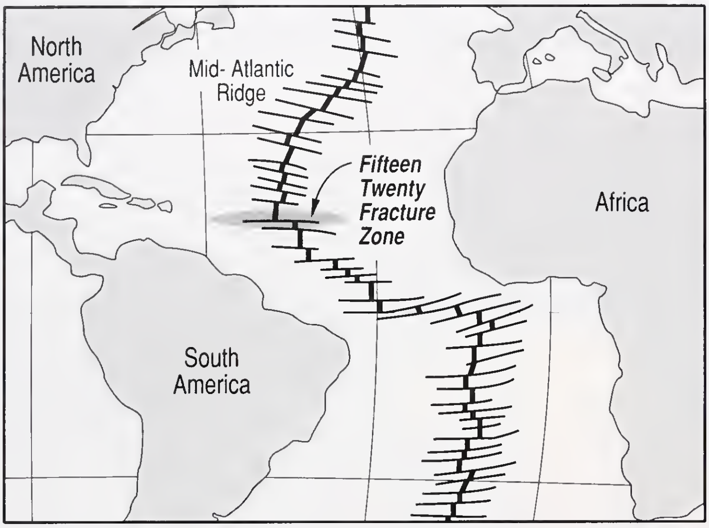
Gary Bond

When the 1991 WOCE comparison/training exercise aboard R/V Akademik Vernadsky *extended over the 4th of July, the Soviet hosts designed this poster in honor of the occasion.*

Dorman later spent three weeks in the USSR visiting some 20 research institutions. He returned with a number of interinstitutional agreements, and more have followed. Many WHOI scientists have enjoyed fruitful cooperative work with Soviet colleagues. As we went to press, Nick Fofonoff had just returned from three weeks in the USSR for follow-up work on the 1989 *Vernadsky* cruise. Terry Joyce, who heads the Hydrographic Programme Office of the World Ocean Circulation Experiment (WOCE), was just back from a comparison/training exercise aboard *Vernadsky* to calibrate instruments and sampling and analysis techniques for WOCE field researchers from the USSR, the UK, Spain, and the US. Geologist Lloyd Keigwin was aboard the Russian vessel *Akademik Vinogradov* for seafloor coring as part of his work on the paleoceanography of the northwest Pacific. Colleagues from our Woods Hole neighbor institution, the US Geological Survey Branch of Atlantic Marine Geology, were at Lake Baikal in south

central USSR, participating in a several-year cooperative study of the paleoclimatic record laid down in the sediments of the world's largest, oldest, and deepest lake. In addition, some 66 Soviet scientists have visited WHOI in the past 18 months to work on a variety of projects.

Many Soviet research vessels are large and can easily accommodate guest investigators. When the opportunity to join a Soviet cruise arises, the lead time on the invitation is often short, obviating access to traditional US government funding sources that require a several-month grant proposal process. Dorman has made director's discretionary funds available to help in these situations. For example, these funds enabled Geologist Henry Dick to join a Barbados-to-Hamburg research voyage of R/V *Akademik Boris Petrov* during November and December 1990. The cruise focused on Mid-Atlantic Ridge dredging at the Fifteen Twenty Fracture Zone and resulted in significant new information about the evolution of ocean crust. One of several discoveries was location of the first large body of dunite ever found along the ocean ridges. Dunite is formed by magma upwelling from the Earth's mantle, and study of these rocks provides important information about the "plumbing system" magma follows from the mantle to the mid-ocean ridges.



During a research voyage aboard R/V Akademik Boris Petrov *last year, WHOI Geologist Henry Dick was among the research party that discovered a large body of dunite at the Fifteen Twenty Fracture Zone on the Mid-Atlantic Ridge. Dunite is formed when magma upwells from the Earth's mantle, in this case emerging on the mid-ocean ridge.*

WHOI Coastal Research Center (CRC) Director David Aubrey is organizing a comprehensive research initiative to examine how Black Sea water quality is affected by land use practices in surrounding river basins. CRC is cosponsoring an October conference in Varna, Bulgaria, on Black Sea pollution of river origin, and helping to develop a 10-year plan for collaborative Black Sea science and policy research.

To help with international communication, WHOI sponsors telemailboxes in Sevastopol at the Institute of Biology of the South Seas and the Marine Hydrophysical Institute, and in Moscow at the General Physics Institute. This allows Soviet and American scientists to communicate using computer-generated messages that travel over long-distance telephone lines. Messages can be typed at the originator's convenience and then picked up and answered at the receiver's convenience, which helps to overcome time-zone differences and other glitches in long-distance communication. (Facsimile lines are few and hence overused, and Federal Express takes about two weeks.)

The WHOI Marine Policy Center staff has a collaborative project with the Soviet Institute for World Economy and International Relations, and one of their Soviet colleagues, Raphael Vartanov, served as Guest Editor in the planning for this issue. Our thanks to him for drawing up the list of Soviet authors, helping us contact them, and shepherding the

articles on their path to the magazine staff. Vartanov's byline appears on two articles, one on the development of Soviet Ocean policy, and another, coauthored with WHOI Marine Policy Center Director Jim Broadus, on the concept of global environmental security as it applies to the world's oceans.

Assembling this issue has been a challenge: The Soviet view of deadlines is rather different from the American interpretation. Communication between the USSR and the US is still largely primitive, and we were working with manuscripts translated from Russian, in some cases, by people not altogether familiar with the English science vocabulary. We had neither the time nor the language skills to check, as we usually do, the accuracy of our editing with the authors. For most of the articles, the best we could do was ask someone in the US familiar with the subject to review the edited manuscripts. We regret any misinterpretation or errors that may have lingered, and we are grateful to our US reviewers. They are acknowledged at the end of each article.

The Soviet Union is a very large country. We found ourselves referring frequently to an atlas while preparing this issue, so we have provided a map of the Soviet Union on pages 46 to 47 that may be helpful to our readers.

As the winds of change sweep the Soviet Union, we've enjoyed the opportunity to learn about marine science and life in the USSR. A number of our US authors and other contacts have noted the warmth and hospitality of the Soviets they have encountered in various walks of life. "We felt a wonderful sense of camaraderie on board, even though we could not speak Russian," author Stella Livingston writes. "Communication does not always require language...My short visit touched me deeply and I returned home determined to learn their language...to develop a much greater understanding of the Soviets' rich and deep culture." We invite you to share and enjoy their experiences.

Vicky Cullen

David Gray

The 133-meter Soviet research vessel Akademik Vernadsky *called at the WHOI pier in June of 1989. Special tours and activities were arranged for the Soviet crew and scientists during their two-day visit, and several WHOI people departed with the ship to participate in a month-long Gulf Stream cruise.*

Diving the Soviet *Mir* Submersibles

Cindy Lee Van Dover

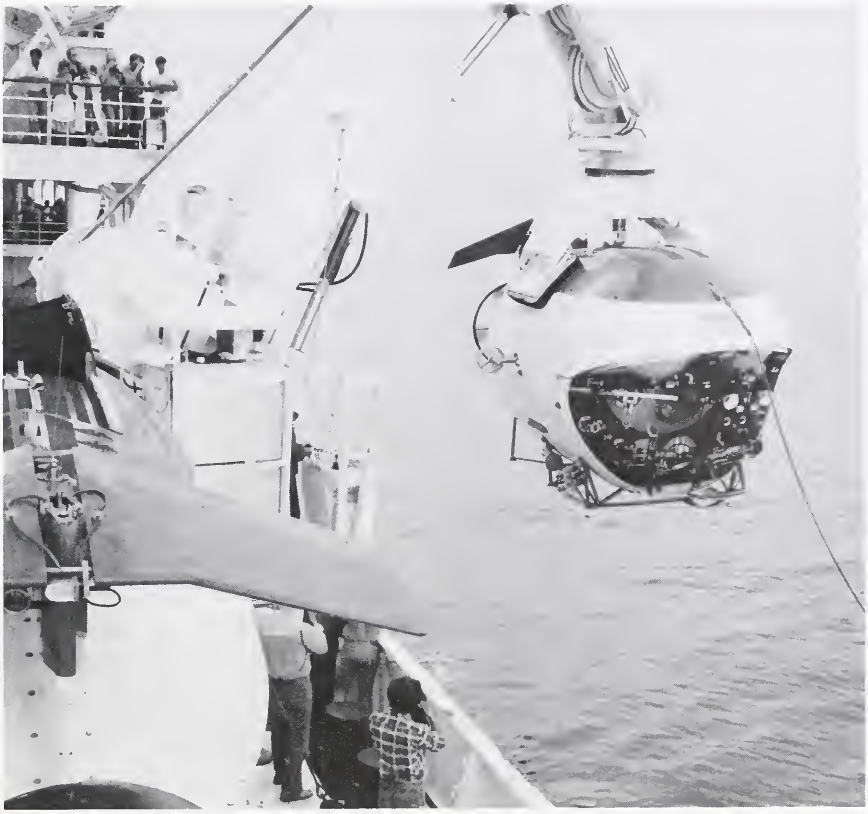
R/V **Keldysh** *can support 130 people in 18 laboratories, and she carries two special pearls: the pair of small, three-person submersibles,* **Mir 1** *and* **Mir 2.**

As we pass beneath the Golden Gate Bridge on our way out to sea, I look up and see the gold hammer and sickle on red emblazoned on the immense stack of this 300-plus foot ship. It is October 1990. My home for the next three weeks, the research vessel *Akademik Mstislav Keldysh*, is the flagship of the P.P. Shirshov Institute of Oceanology and one of the prides of the Soviet Oceanographic Fleet, and rightly so. Hailing from Kaliningrad, she is well fit for oceanographic duty, with enough winches, davits, and A-frames to accommodate any requirement. She can support 130 people in 18 laboratories, and she carries two special pearls: the pair of small, three-person submersibles, *Mir 1* and *Mir 2* (*Mir* means "peace"), tucked protectively beneath her hydraulically activated awnings on the starboard aft deck. The identical-twin *Mirs* were built for the Soviets by the Finnish company Rauma-Repola in 1987 and 1988. Blimplike in shape, they sport a top deck painted international orange for increased visibility on the water surface.

Launching the Pearls

On this sunny morning in Monterey Bay, I watch the preparations for the day's dives. The routine is familiar to me: wrench-bearing technicians top off hydraulic lines with fluid and adjust ballast; a pilot peers through the forward viewport of *Mir 1* as he runs through predive checks of manipulator functions; and replenishing supplies are passed into the crew sphere. With the submersible ready to go, the diving team, outfitted in sky-blue jumpsuits, pauses ritually at a threshold. The three then emerge in order—copilot, scientist, pilot—and climb up to the hatch and into the sphere. A complement of ship's crew and scientists man the railings to watch the launch progress. *Mir 1* is hoisted off the deck with a crane and lowered over the side into the water. A swimmer from an inflatable lifeboat leaps onto the sub and deftly releases the lift line. A second boat tows *Mir 1* away from the ship and stands by while the pilot completes the predive checks. With checks complete and all lines clear, *Mir 1* begins her 60th descent. An hour later, *Mir 2* is launched.

At 60 dives each, the Mir boats are only babies compared to the Woods Hole Oceanographic Institution's submersible *Alvin*, which I recently piloted on her 2,400th dive. But the *Mirs* are first-class submersibles, destined for a future of technically and scientifically successful dives. Already, the Soviets have used them to explore seafloor sites throughout the Atlantic and Pacific oceans. They have visited dive areas



The Keldysh *crew launches* Mir 1 *while* Mir 2 *waits its turn on deck.*

made familiar by *Alvin's* work, then moved outward to virgin seafloor where they continually find new features of interest. In the next year or two, the *Mirs* will likely be the first deep-diving boats to work the unexplored seafloor of the Indian Ocean, where important scientific observations await. Designed and cleared to dive to 6,000 meters, the *Mirs* can explore vast areas of the ocean's bed that are inaccessible to *Alvin*.

Pilgrimage to Monterey and "Cannery Row"

We anchor off Monterey. Ship's crew and scientists are given unrestricted leave to go ashore, and the ship's cutter is pressed into service as a ferry. For many of the scientists, and for myself, too, the visit to Ed Ricketts's Cannery Row laboratory is something of a pilgrimage. One Soviet biologist, Lev Moskalev, shows me his well-thumbed copy of John Steinbeck's *Cannery Row*, wherein Ed Ricketts, a classic marine biologist, is so colorfully portrayed. Lev Moskalev is himself a great naturalist; his laboratory notebooks are filled with careful observations, detailed sketches, queries, and theories. Some of his queries are directed at my own research, and these stimulate a congenial debate over our diverse interpretations of the natural history of an animal we have both studied.

As the Soviets invade the small town of Monterey, they invite everyone they meet to an impromptu open house aboard *Keldysh*. The cutter runs continuously, carrying visitors to the ship. The guests are given tours, invited to meals, and asked to join crew members in their staterooms for tea, wine, or vodka. Laughter and singing resonate in the

passageways as the Russians entertain their guests with unbounded graciousness and hospitality. At midnight, under moonlight, the last guests hug their new friends goodbye. With tears in their eyes, they reluctantly board the cutter to leave the ship. We sail away at dawn.

A Record Dive to 4,065 Meters and an Abyssal Plain

Another day, in deep water off Ensenada, Mexico, it is my turn to dive. I pause at the threshold wearing my borrowed jumpsuit and sporting the gold dolphins that mark me as a US Navy-qualified, deep-submersible pilot. As copilot on this dive, I am first to step out and climb into the submarine. I am followed by Julia Tchindonova and Dima Vasilyev. Our dive plan is straightforward. As the scientist on board, Julia will study the distribution of large zooplankton in the water column. We descend slowly, 10 meters per minute, with the floodlights on. Julia peers intently out the forward viewport, identifying and counting the organisms that pass through a 1-cubic-meter frame held by one of the manipulators. Between 500 meters and 1,000 meters, we pass through a layer that is the daytime home of giant squid. Attracted to our lights, they approach the submarine and keep us glued to the viewports. These animals ascend to the surface at night to feed, where they are eagerly hooked beneath deck lights by the ship's sailors. Squid flesh supplements the galley's stores; squid beaks are dissected out and kept as trophies.

It is a long, six-hour descent that ultimately takes us to 4,065 meters and an abyssal plain of soft brown sediment. For me, it is a personal depth record I won't be able to exceed in *Alvin*. On the bottom, the pilot, Dima, passes control of the submersible to me. I find the sub agile, skimming over the soft sediment surface with ease as I operate the joystick. Dima takes over and shows his skill and dexterity with the manipulators. In every respect, he demonstrates the professionalism of an experienced deep-submersible pilot.

Emory Kristof © National Geographic Society

Mir 1 surfaces at dusk for recovery following a dive.

Sampling the Sea and the Senses

On days that the submersibles do not dive, the ship is occupied with other scientific activities. For example, a large (150-liter) water-sampling bottle is repeatedly serviced, hoisted off the stern, and lowered to different levels in the water column where the bottle is tripped closed and the sample is returned to the surface. Once on deck, water is siphoned from the bottle and distributed to a myriad of laboratories for a carefully orchestrated suite of productivity. This research program is being undertaken on a global scale; on this voyage of *Keldysh* alone, hundreds of samples along

a transect that stretches from one shore of the Pacific Ocean to the other have been collected and analyzed.

Two men stand as silhouettes against the sun that sets over the rugged desert mountains of the Baja Peninsula. With intense concentration, they parry and thrust their fist-sized chessmen across a checkered field. As I quietly enjoy this decidedly Russian vignette, Anatoly Sagalevitch approaches. Sagalevitch—his name gave me a pause at first, but now the syllables tumble out in a satisfying rhythm: Sa-ga-le'-vitch. He is an admirable man: scientist, engineer, skilled pilot, and outstanding leader. The *Mirs* operate successfully because of his talents. As we look out over the surface of the becalmed sea, we speak in simplest Russian of the mysteries that lie beneath us, and we speak of our submersibles. Though our sentences are short and the conversation brief, we reach beyond politics and pretenses to establish a professional bond that will last throughout our careers as scientists and pilots.

Dudley Foster

Author Cindy Van Dover, with camera, and Brian La Flamme, University of Washington, examine a sulfide mound covered with tube worms. The sample was recovered by Alvin *during a 1988 dive to deep-sea vents on the Juan de Fuca Ridge off the coast of Washington.*

Of Tube Worms, Mineral Chimneys, and Slurp Guns

We sail up the Gulf of California—the Sea of Cortez—and the *Mirs* are again readied for dives. Though *Keldysh* sails smoothly over the water, strong winds have pushed up sizable waves that threaten to cancel our dive plans. Word is finally passed to carry on with the dives, and I climb into *Mir 2* with two other pilots, Dima and Sagalevitch. On this dive, Sagalevitch and I share the science program. We will dive on hydrothermal vent sites and use a slurp gun to sample zooplankton in the water column around the vents. Despite the rough seas our launch is flawless and we descend 25 meters per minute to the seafloor. Once on the bottom, the submersible's sonar picks up return signals from mounds of sediment. We drive toward one and find a vast colony of tube worms, bacterial mats, and warm shimmering water at the top. Sagalevitch goes to work, positioning the submersible without stirring up the sediment, setting up the pump, and sampling the water. With one sample collected, we move off to additional stations along a transect away from the vent site. When the samples are processed back in the ship's laboratory, we will find out if bacterial production at the vent supports an enriched zooplankton community in the overlying water column.

As we sample, I peer out the viewport and see the eerie lights of *Mir 1* working nearby. The two submersibles often dive together, each serving as a rescue vehicle for the other. Eight hours into the dive, we finish sampling and confer with the mother ship about weather conditions. The sea state has worsened, we are told, and the decision is made

Emory Kristof © National Geographic Society

Mir 1's personnel sphere accommodates Anatoly Sagalevitch, at left, head of the Laboratory of Manned Submersibles for the P.P. Shirshov Institute of Oceanology, and National Geographic Photographer Emory Kristof during a series of dives in 1989. The two men have collaborated for many years to develop advanced underwater photographic techniques for submersible use. They have just completed a set of dives at the Titanic *site (see photo below) for an IMAX® film.*

to stay submerged for another eight hours. This is a luxury *Alvin* cannot afford. *Alvin's* power capacity limits its workday to 8 or 9 hours, although in an emergency she can stay submerged up to 72 hours. The *Mirs* routinely submerge for 16 hours with full power (although shorter dives are planned whenever a woman is scheduled to dive); for emergencies, the *Mirs* also have extended submergence capabilities.

With our extra bottom time, we decide to tour the hydrothermal mounds in the area, traversing from one site to another using the sonar to locate targets. Each mound is different. Some have profuse animal communities with diffuse venting of low-temperature water; others are ornamented with pagodalike mineral chimneys and inverted hot-water pools; and still others appear as relicts of former hydrothermal activity. We select one hot-water site and Sagalevitch begins to collect physical measurement sets that he will use to estimate the hydrothermal energy emitted by the vent.

One of the Mir *subs captured the other exploring near one of* Titanic*'s side propellers in a video image made by a recently designed WHOI camera system loaned for the* Titanic *expedition. A joint development effort between WHOI and Sony Corporation, it is the highest resolution deep-sea video camera system in existence today. Other corporations involved in the development include LNG Technical Services, Fujinon Inc., Benthos Inc., and Ocean Images, Inc.*

It is well into night by the time we return to the surface. The seas are still unsettled and the recoveries are prolonged. Finally, sheets of water flow past the viewports as we are plucked from the sea and come to rest on deck. Elvira Shuskina, the chief scientist on the cruise, takes over, carefully transferring samples from the collecting chambers to bottles for preservation. The next day, Elvira and her colleagues sort through the samples and make a preliminary organism count. With considerable excitement, they report finding peculiar-looking larval stages of some of the animals that colonize the vents. Eventually, we hope that analyses of these samples and others will help us understand how animal communities persist at vent sites and how new vent sites are colonized.

The Rhythm of Life at Sea

Three weeks on my adopted ship pass by far too quickly. Rituals like tea with the *Mir* pilots and technicians in the morning, and sauna with the women scientists twice a week, begin to define the rhythm of life at sea. Friendships develop rapidly within the closed society of a ship's community, and it is only reluctantly that I leave my new friends and colleagues.

I spend my last evening on board first with the scientists I worked with and then in the company of the submersible crew. Sagalevitch draws the evening to a close with a ballad that tells of the courage and dedication of those who dive to the seafloor. His voice alone carries the melody at first; then, one by one, the other men join in until a chorus of 20-odd sings to me. Finally, I pick up the Russian words, and we sing the last lines together.

Sagalevitch draws the evening to a close with a ballad that tells of the courage and dedication of those who dive to the seafloor.

Cindy Lee Van Dover is a Postdoctoral Investigator in the Biology Department of the Woods Hole Oceanographic Institution (WHOI) and a pilot of WHOI's submersible Alvin.

Editor's Note: As we went to press, discussions were being held by the Woods Hole Oceanographic Institution, The P.P. Shirshov Institute of Oceanology, Imax Corporation, and other corporations on the possibility of a major US-USSR cooperative deep-submergence expedition for the Mirs *in 1992 and 1993.*

The Oceans and Environmental Security

James M. Broadus and Raphael V. Vartanov

Environmental affairs have taken on geopolitical importance. The most prominent recent example is Iraq's intentional release of Kuwaiti oil into the Persian Gulf, in an apparent attempt to impede a military assault and to contaminate Saudi Arabian drinking water. Issues of responsibility, liability, and compensation for the resulting environmental damages have been simplified somewhat in that case, because a vanquished Iraq was forced to accept terms of military disengagement. Similar issues arise in other cases involving the marine environment, however, and resolving them cannot depend on military victories. Quite the opposite, an important goal of their resolution is to avoid or contain international conflict, and to prevent or minimize envi-ronmental damage, toward enhancing "environmental security."

Imagine the complications if Soviet resources and livelihoods had borne the brunt of damages from the *Exxon Valdez* oil spill. How would international institutions assure the proper assignment of responsibility and a fair compensation for losses? Experience with transboundary effects from the Chernobyl disaster of 1986 suggests that international mechanisms for dealing with accidental environmental damages are neither well developed nor effective. In fact, widely acknowledged mechanisms have evolved since World War II to govern oil transportation practices, to assign responsibility for accidental oil spill damages, to guide the resolution of disputes, and to counsel the allocation of compensation. Comparable mechanisms for the more complex, potentially more dangerous, problem of other hazardous seaborne cargoes have yet to be worked out.

US Coast Guard

The geopolitical importance of environmental affairs is exemplified by the assault on Persian Gulf air and water when Iraq damaged Kuwaiti oil wells.

A similar but less discussed problem involves contamination from nuclear devices. Published reports estimate that 50 nuclear weapons and 11 reactors have been lost at sea, all by the US and Soviet navies. In 1989, for example, a Soviet *Mike*-class nuclear-powered submarine, believed to be carrying two nuclear torpedoes, sank in the Norwegian Sea. Icelandic fishermen worried that mere suspicion of radioactive contamination of their fish products could damage their export markets. In a broader context, people of some coastal countries, especially islands, are concerned that other countries' atmospheric emissions threaten to inundate them with rising sea levels caused by global warming.

US Coast Guard

Questions of liability and compensation for environmental damages must be answered. Here, workers attempt to contain some of the 300,000 gallons of oil spilled into the San Pedro Channel in February 1990 when an anchor sliced through the US-owned American Trader's *hull. The photo shows part of British Petroleum America's intense cleanup effort.*

The Environment and International Security

The concept of environmental security is gaining currency as a way of thinking about international environmental management. It draws on the widely understood notion of international, strategic interdependence (in facing threats of nuclear war or economic collapse) to focus attention on the similarly shared exposure to threats from global environmental degradation. Implicit in the concept is a direct link to a conventional understanding of international security arising from the potential for conflict over resource use and environmental practices.

For over a year, the Institute for World Economy and International Relations (IMEMO) and the Woods Hole Oceanographic Institution (WHOI) have combined forces to compare thinking on the concept of environmental security as it applies to the world's oceans, to define the concept more precisely, and to identify opportunities for cooperative US-USSR actions. Within the USSR Academy of Sciences, IMEMO is a major center of Soviet scholarship on world trends in economics, politics, organization, and strategic relations. IMEMO's Department of Oceans and Environment is a counterpart to WHOI's Marine Policy Center (MPC) in terms of disciplinary orientation (law and economics), research emphasis (oceans, environment, and international relations), and location within a larger research organization.

The collaborative project was initially suggested by IMEMO researchers following a visit by WHOI/MPC Director James Broadus in 1987 that was sponsored by the USSR Academy of Sciences. The project, sponsored by the John D. and Catherine T. MacArthur Foundation and the Peace Research Institute of the USSR Academy of Sciences, formally began in December 1989. Since then over 30 Soviet and American scholars have taken part in three joint workshops (two in Moscow and one in Woods Hole), numerous exchanges, and collaborative analyses of selected cases.

The project is unusual since it is truly a joint effort. All elements of the planning, research, and writing are shared. Our research is interdisciplinary, combining the efforts of specialists in economics, law, international relations, ecology, and ocean science. Participation by the project's two natural scientists, Arthur Gaines and Chris Haney, has allowed our social scientists to incorporate richer treatments of ecosystem processes in their analyses than is often possible. Among cooperative US-USSR bilateral ocean studies, this one is distinctive in its emphasis on social science rather than natural science. Through our work we have reached the conclusion that cooperation in both of these areas of science is vital. Early in our collaboration we formulated a working definition:

> *Environmental security is the reasonable assurance of protection against threats to national well-being or the common interests of the international community associated with environmental damage.*

Critical problems of international environmental security were determined to be those that are likely to destabilize normal relations between nations and provoke international countermeasures.

Sensible management of the pristine and vulnerable antarctic marine environment is one of the authors' environmental security project areas.

Threats to Ocean Environmental Security

Using this definition and these criteria for guidance, our joint research team has identified eight problems of ocean environmental security that are of high mutual interest to our two countries. Research is now focused on analyses of these problems. Three of them—hazardous materials transport, nuclear contamination, and sea-level rise—have already been mentioned. The other five also deserve brief introductions.


Skip Owen

North Pacific Fisheries Depletion. This is a complex and multifaceted problem in the Bering Sea and adjacent North Pacific fishery. American and Soviet enforcement of their 200-mile exclusive fishery jurisdictions has driven international fleets, especially Japanese, Korean, and Taiwanese, onto the high sea beyond. However, an "island" of high sea that is surrounded by American and Soviet jurisdiction, called the "donut hole," provides an enclave where straddling fish stocks continue to be fished toward depletion. The Asian fleets have meanwhile begun using very long driftnets in the high seas. These are implicated in the "incidental" losses of nontargeted fish species, seabirds, and protected marine turtles and mammals. There are also charges of illegal taking at sea of Soviet, American, and Canadian salmon. The US and USSR governments are under some domestic political pressure to extend their fisheries jurisdictions into the donut hole, beyond the limits allowed by international law. An environmentally secure solution will most likely

require a multilateral scheme for cooperative management of North Pacific fishery resources on an ecosystems basis.

Arctic Ocean Sensitivities. Northward from the Bering Sea, the Arctic Ocean remains one of the planet's least polluted environments. It is also unusually sensitive, in two ways. First, harsh conditions, short food chains, and a low level of species richness render Arctic Ocean ecosystems highly vulnerable, while low temperatures slow the breakdown of many pollutants and extend both their residence time and geographic range within the environment. Second, this environment is an important theater for sensitive military operations by both superpowers. As economic activities such as mining, oil and gas production, and shipping push farther northward, maintaining environmental security for this region will require accommodation and cooperation for both sensitivities.


S.C. Delaney/EPA

The Southern Ocean. Another cold, harsh, pristine, and vulnerable marine environment surrounds Antarctica. Economically, the Southern Ocean supports limited fishing, minimal navigation, and no minerals development. Since 1959, many activities in this ocean have been governed by a limited club of nations participating in the Antarctic Treaty regime. Most of the Southern Ocean has thus been demilitarized, and national claims to maritime jurisdiction have been placed in abeyance. Future management of the Southern Ocean and its resources, however, is a matter of great controversy. Many nations not involved in the Antarctic Treaty system wish to substitute a United Nations-based regime of universal participation. Basically, three different possibilities exist for future management of Antarctica and the Southern Ocean: 1) a strictly preservationist regime, setting the entire region aside as a world park or nature preserve; 2) a multilateral conservation system allowing controlled multiple uses and limited resource exploitation; and 3) a territorial division partitioning the region into separate national jurisdictions.

Land-based sources are estimated to account for as much as 90 percent of total marine pollution. They are one of the most urgent priorities for marine environmental protection.

Land-Based Marine Pollution. Land-based sources are estimated to account for as much as 90 percent of total marine pollution, yet international control efforts address vessel-source pollution almost exclusively. While specific instances of land-based marine pollution are mostly confined to individual nations, the problem is widespread globally and is one of the most urgent priorities for marine environmental protection. Project investigators have identified several ways in which marine pollution is a definite problem of environmental security. The pollution may cross national boundaries or affect shared resources, or, more commonly, several countries may contribute differing amounts of pollution to a shared water body. Local marine pollution can be exported indirectly,

through tourism or through contaminated or suspect seafood exports. Even the well-being of foreigners who may never visit the polluted area or consume its exports can be threatened by the despoliation. Our research team is comparing the situation in two regions: the Black Sea (to which the USSR contributes a large share of pollution) and the Gulf of Mexico (with major US pollution loading).

International Law of the Sea. The United Nations Convention on the Law of the Sea (UNCLOS) contains the most comprehensive statement of international environmental law ever negotiated and shows great potential as an instrument of ocean environmental security. However, neither the US nor the USSR has ratified the treaty (in large part because of objections to its seabed mining provisions), and the treaty has not entered into force (see The USSR and the International Law of the Sea, page 35). Its fate is uncertain, and so is the legal force of its environmental provisions. Recognition by UNCLOS that countries have an obligation to "protect and preserve the marine environment" nonetheless stands as evidence that this obligation has been adopted as customary international law. We are working to identify the practical implications of this legal obligation, including any changes in American and Soviet domestic laws and practices necessary to conform fully to UNCLOS.

From our examination of these cases, a number of cross-cutting themes, listed at left, has emerged. The study teams are now concentrating on determining exactly how each theme relates to each case. Obviously certain themes are more central to some cases than to others. Coastal population dynamics are directly tied to land-based marine pollution, for example, but population dynamics affect North Pacific fisheries depletion only indirectly, through increased demand for fish products. Military conversion opportunities figure more prominently in the Arctic and in nuclear contamination cases than in land-based pollution or law of the sea. Although the nature of global perspectives differs from case to case, most of the other cross-cutting themes are important considerations for all eight cases.

Cross-Cutting Themes in Ocean Environmental Security Cases

- Global perspectives
- International cooperation
- International organizations
- Technology & technology transfer
- Military conversion opportunities
- Responsibility, liability, & compensation
- Monitoring data & information management
- Criteria (net benefits, etc.) & standards
- Environmental consequences of population dynamics
- Future prospects

Cooperation Despite Differences

Working together on this project, we have discovered possible US-USSR differences in outlook and scholarly approach. For example, Soviet scholars seem to favor more holistic and comprehensive subject treatments than many of the Americans, who have tended toward more reductionist, analytical approaches. As a group, the Soviet scholars also seem to be somewhat more internationalist in orientation than the Americans. The Soviets sometimes push harder for consideration of multilateral and global approaches to problems, while the Americans tend to look first to bilateral bargains or regional arrangements. The Soviets seem to exhibit more faith in international institutions than do the Americans, and they may be less comfortable than the Americans in dealing with uncertainties and probabilities; instead, they tend to call for institutional arrangements that eliminate risk and provide security guarantees.

Of course these differences are only subtle tendencies, and they may depend more on the individuals involved than on their nationalities. Despite group tendencies, the most insistently holistic and enthusiastically internationalist individuals were probably Americans; some of the

Soviet scholars, on the other hand, were as analytically reductionist as any of the Americans. Through our work together we have succeeded in forming a single team. We have thus become the closest of colleagues, and continue to learn from each other. Each of us has been affected personally by getting to know the others' families, and we look forward to the day when our families can get to know each other too.

We are convinced that joint US-USSR research on the current health and future of the world's oceans has special significance. The two superpowers have immense influence in international affairs. Their growing willingness to become leaders in global environmental conservation, combined with their abiding interest in the world's oceans, provide an open avenue for positive change in environmental security. Through this opportunity for US-USSR interaction, we hope to contribute to the enhancement of ocean environmental security for everyone.

James M. Broadus is Director of WHOI's Marine Policy Center and co-principal investigator on the cooperative IMEMO-WHOI project, Environmental Security and the World Ocean.

Raphael V. Vartanov is Head of the Section on Ocean Development and Environment, IMEMO, USSR Academy of Sciences, and co-principal investigator on the cooperative IMEMO-WHOI project.

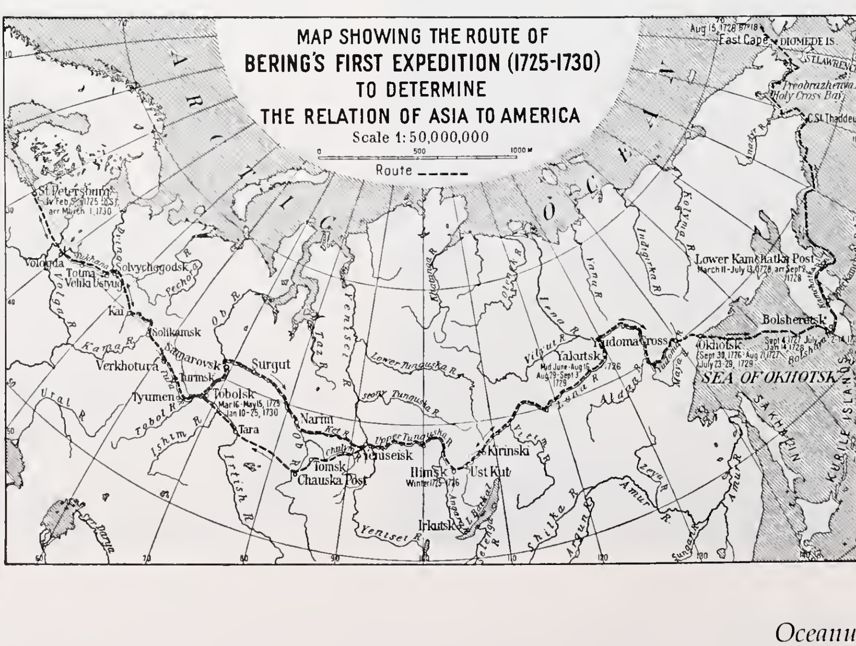
The History of Soviet Oceanology

Leonid M. Brekhovskikh and Victor G. Neiman
with Traci Watson

Ground-breaking literary and philosophical works are often permeated with attributes of their country of origin. The critical approach known as deconstructionism, for example, is unmistakably French, and the ideals of the Renaissance seem uniquely Italian. But scientific ideas are concepts-without-a-country, stateless wanderers of human knowledge. The big bang theory, evolutionary theory, the law of gravitation—all carry no sense of national identity. Instead, a scientific result, as a part of genuine understanding, belongs to the whole of mankind. Therefore the achievements and problems of one country's scientists are also the achievements and problems of scientists everywhere. We hope that our readers will keep this in mind as we briefly explore the history of Soviet oceanology.

A Tragic Beginning

The birth of Russian oceanology was, to put it mildly, inauspicious. In 1725, Vitus Bering was ordered by Peter the Great to determine whether Asia and America were connected. Bering trekked for two-and-a-half years by horse, river barge, and dog sled from the capital city of St. Petersburg on the Baltic coast to the eastern edge of Siberia, considered



Bering's first expedition is shown graphically: the dotted line traces Bering's path from St. Petersburg to the Lower Kamchatka Post, the starting point for the sea voyage, and up the coast through the Bering Strait. The map shows routes for both outbound and return land journeys.

Bering's Voyages, Vol. 1, American Geographic Society, 1922

savage and uncivilized territory by Western Europeans. The expedition embarked from the mouth of the Kamchatka River and followed the Siberian coast north for 30 days before turning back home without a single sighting of America. Bering and his men had, without realizing it, sailed between the easternmost point of Siberia and the westernmost point of the Alaskan mainland, a passage now known as the Bering Strait. But in his report to the Russian government, Bering only reported that he did not see land; in 1732, he was ordered to sail again.

Once more he crossed the Russian continent to the Siberian coast. Preparations for the cruise dragged on for almost 10 years, and the voyagers did not depart until the spring of 1741. After three months of sailing, the expedition landed on Kayak Island off the southeastern coast of Alaska, near what is now the Alaska-Canada border. They headed for home almost immediately, but ferocious storms, lack of water, and advanced scurvy forced them to seek land in November. The voyagers spent the winter on a treeless, gameless island 300 miles from their home port and watched storms batter their ship beyond use. Of the original 77 crew members, 45 survived to build a new ship from the timbers of the wreck and sail uneventfully to Siberia. Bering was not among the survivors; the expedition leader had died at age 60, a month after landing on the island that was christened Bering's Island in his honor.

An unknown artist drew Stellar's sea cow based on a description by Sven Waxel, a commanding officer on Bering's second voyage and one of the few Europeans known to have seen the animal.

Drawing from *Bering's Voyages*, Vol. 1, American Geographic Society, 1922

Among the voyagers who did survive was the German natural historian Georg Stellar. Stellar took detailed notes on the plant and animal life he observed in America, at sea, and on Bering's Island. Appended to his official account of the voyage are careful delineations of several island species, which he had ample leisure to observe. His works include one of the best descriptions of Stellar's sea cow, a type of gigantic manatee that became extinct 25 years after Stellar's report to the Russian government. However, neither Stellar nor any other crew member saw fit to record information about the ocean itself, aside from a few soundings taken near land for practical purposes. This neglect was typical of the time. Until the mid-1700s, the ocean was often thought of as nothing more than an obstacle to the discovery of unknown land flora and fauna, a barrier to be traversed as quickly as possible. Few Russian scientists seemed to consider the ocean itself a worthy object of study.

Birth of a Science

It was not until the 1750s that voyagers on an investigative cruise to the arctic seas first collected information on ocean currents and ice-drift patterns. At the trip's end, the data was handed over to Mikhail Lomonosov, an experimental chemist and theoretical physicist who is often considered Russia's first great scientist. Lomonosov, who formulated an atomic theory of matter predating Dalton's and a kinetic explanation for heat, turned his sharp scientific insight toward analyzing the arctic expedition data. His findings, submitted to the Swedish Academy of Sciences in 1761 and 1763, included the first systematic classification of ice, the first discussion of polar-ice drift, and a description of northern currents.

Lomonosov's pioneering investigations helped elevate Russian oceanology from the purely practical study of navigation to the status of a science.

Only 62 years after Bering's disastrous voyage to determine whether Asia and America were completely separate continents, the first Russian ships circumnavigated the globe. Admiral Ivan Kruzenstern commanded the voyage of the research vessels *Nadezhda* and *Neva* from 1803 to 1806 as they collected hydrological data in the Atlantic, Pacific, and Indian oceans. Other voyagers soon followed in Kruzenstern's wake. Russian scientist and sailor Otto Kotzebue directed two round-the-world cruises between 1815 and 1826, the first in *Ryurick*, a 180-ton wooden brig. On his second voyage, Kotzebue took the naturalist Emil Lenz, who is perhaps best known for describing the behavior of electrical current induced in a wire by a magnet or coil and who also invented the first bathymeter for water-sample collection and water-temperature measurement. Lenz's analysis of the extremely accurate data he collected on the voyage enabled him to describe and explain some of the fundamental aspects of oceanic salinity.

Discoveries in the Southern Polar Ocean

Overseeing almost all of the map work for Kruzenstern's circumnavigational cruise was a 24-year-old naval officer named Faddei Bellingshausen. His competent leadership and passion for cartographic accuracy during the three-year voyage were not unnoticed: He was chosen by agents of Emperor Alexander I to head the first Russian expedition to the South Pole. In 1819, the three-masted sloops *Vostok* and *Mirnyy* embarked from St. Petersburg under Bellingshausen's command. Five months later, after threading their way through huge packs of polar ice, the voyagers caught the first-ever glimpse of the continent of Antarctica, though they did not recognize it as such at the time. [*Editor's Note: Americans like to believe that the first person to see the Antarctic continent was an American sealer, Nathaniel B. Palmer, who was working in the area at the same time.*] Over the course of two years' sailing time, *Vostok* and *Mirnyy* travelled over 55,000 miles, sailing completely around the antarctic continent and discovering 29 islands in the process. Though determined to sail as far south as possible, Bellingshausen was also zealously conscientious about his crew's welfare and went to uncommon lengths to prevent scurvy and other illnesses.

This portrait of Faddei Bellingshausen was painted within a few years of his expedition to Antarctica, when he was about 40 years old.

The Voyage of Captain Bellingshausen to the Antarctic Seas 1819-1821, Hakluyt Society, 1945

In his report to the emperor, Bellingshausen lamented that no naturalists accompanied the voyagers to the Southern Ocean. Despite this oversight, the scientific findings made over the course of the three-year expedition were considerable. The commander collected numerous marine organisms in a net dragged alongside the ship, and specimens of

Vostok and Mirnyy encountered huge icebergs as they sailed close to the antarctic continent. Paul Mikhailov, the expedition's artist, painted this scene of sailors hacking out blocks of ice to melt for drinking water. They also blasted chunks from the icebergs with cannons.

The Voyage of Captain Bellingshausen to the Antarctic Seas 1819-1821, Hakluyt Society, 1945

marine birds were acquired by shooting them out of the sky (the accepted procedure for specimen collection at the time). Crew members regularly took readings of the water temperature and specific gravity at different depths. These measurements constitute the first characterization of extensive tracts of the southern polar ocean.

Bellingshausen constantly performed simple hydrological experiments, demonstrating, for example, that water temperature drops and specific gravity rises at greater depths. Just as Lomonosov had been the first to establish a classification system for polar ice, Bellingshausen was the first to define categories of Antarctic ice. He described the Antarctic climate and determined the location of the south magnetic pole with amazing accuracy, even by 20th century standards. His scientific accomplishments demonstrate that Bellingshausen was not just an explorer who took up natural history as a shipboard hobby. His observational precision and continual attempts to explain his data mark him as a gifted scientist as well as a humane and daring sea captain.

Around-the-World Voyages for Science

Bellingshausen's voyage was unrivalled in scientific importance until the last Russian circumnavigational voyage of the 19th century. Under the direction of Admiral Stepan Makarov, from 1886 to 1889 researchers on the corvette *Vityaz* measured water density and temperature at 250 sites in the Atlantic, Pacific, and Indian oceans as well as the Red, North, and Baltic seas. Makarov used this information and the observations of other voyagers to tabulate the first charts of North Pacific water temperatures, which he published in his book *The* Vityaz *and the Pacific Ocean*. In this, his tour de force, Makarov not only analyzed the data collected during his expedition but also expounded on topics ranging from water density in the English Channel to the effect of the Coriolus force (a force to the right in the northern hemisphere and to the left in the southern hemisphere generated by the earth's rotation) on world currents. This massive work, published in 1891 in both Russian and French, won him renown across Europe and a Gold Medal from the Russian Geographical Society. But Makarov apparently was not content with circling the globe, for after

the publication of his book he made two voyages to the Arctic and collected information on the ice and water of the arctic region. The ship employed for both voyages was Makarov's brainchild and pet project, *Ermak*, the first Russian icebreaker. The countless scientific expeditions made by Soviet icebreakers to ice-bound regions of the Arctic are perhaps Makarov's greatest legacy.

Though Makarov and many other Russian scientists devoted themselves to investigations of the world ocean, Russia's inland oceans and bordering seas did not suffer scientific neglect. In the second half of the 19th century, Russian researchers established the first observatories on the coasts of the Black and White seas and began to collect data about their marine life and meteorology. Foremost among those who studied Russia's European seas was Nikolai Knipovich, who led expeditions to the Barents, White, and Baltic seas in the west and the Caspian, Black, and Azov seas in the east over the course of a 45-year career. He drafted the first bottom-relief map and current scheme of the Barents Sea and also provided a wide-ranging, detailed description of the Caspian Sea's hydrology and marine life. His reports not only guided the Russian government's regulation of shipping and fishing on the Caspian but also led to protection of its natural resources. Before Knipovich's time, scientists studying the fish of the Russian seas seldom examined the hydrology of the water in which the fish swam, focusing instead on the prospects for financial gain. Knipovich was one of the first marine biologists to recognize the intertwined relationship between marine species and the physical and chemical qualities of the water they live in.

In the second half of the 19th century, Russian researchers established the first observatories on the coasts of the Black and White seas.

Oceanology After the Revolution

In 1920, after the Revolution, the National Education Committee established the Marine Sailing Scientific Institute (better known as Plavmornin). Although Plavmornin was originally conceived to study only the northern seas, its scope soon expanded to include other seas and selected regions of the world ocean. Plavmornin began its fleet with the wooden, two-masted schooner *Persey*, which carried a crew of 24 and a scientific staff of 16. In its 19-year career, *Persey* made over 80 voyages to locales as far east as the Greenland Sea and as far west as the Barents Sea. Scientists from all disciplines worked together aboard *Persey*; a typical expedition included hydrochemists, marine biologists, and marine geologists. This cooperative approach allowed *Persey* scientists to make advances in fields ranging from ice forecasting to biological productivity of the oceans. Many *Persey* scientists would later author fundamental works in marine hydrophysics, biology, chemistry, and geology. *Persey*'s distinguished career was cut short by a German bomb at the beginning of World War II, but her name did not die when she sank: Today, the second *Persey* serves as a research vessel for scientists studying the western Pacific seabed.

Twenty years after the founding of Plavmornin, the Laboratory of Oceanology (later renamed the P.P. Shirshov Institute, after its first director) was organized for conducting scientific investigations on the open ocean. In the late 1940s, the lab acquired *Vityaz*, a powerboat with a high-capacity winch and the ability to anchor or trawl almost anywhere in the ocean, making it particularly well-equipped for deep-water re-

The Soviet research vessel Akademik Ioffe *was built in 1988 and 1989 for high-range acoustic studies. The ship boasts some 20 laboratories and a computer system for compiling and analyzing data.*

search. In 1949, scientists aboard *Vityaz* made some of the first studies of fauna from deep-water trenches. Over the next 25 years, they studied 18 deep-water trenches, leading to the discovery of a new ultra-abyssal life zone containing hundreds of new species and dozens of new genera.

Scientists on the 25th voyage of *Vityaz* in 1957 discovered the deepest point in the world ocean, a site in the Marianas Trench that bottoms out at 36,161 meters. Soviet marine biologists collected data indicating that life exists even at this enormous depth, and their findings were confirmed by visual observations made on an American dive in the bathyscaph *Triest* in 1960. Deep-sea trawling from *Vityaz* yielded numerous specimens of the odd vent-dwellers known as pogonophorans (also called beard worms), long, thin creatures that live in tubes on the seafloor. Based in part on the samples from the *Vityaz* collections, Soviet scientist A.V. Ivanov suggested, correctly, that the pogonophorans occupy a separate phylum of their own rather than forming a subcategory of a previously known phylum.

Vityaz scientists also discovered previously unknown forms of bottom relief in the Pacific and Indian oceans, and found that ferromanganese nodules and crusts are widely distributed over Pacific abyssal areas. On *Vityaz*'s 31st cruise, researchers first systematically measured currents in equatorial and tropical waters of the Indian Ocean. Current maps based on this data revealed that at depths below 100 meters, there is an eastern equatorial stream analogous to the Cromwell Current in the Pacific Ocean and the Lomonosov Current in the Atlantic Ocean.

Meanwhile, Soviet scientists were also investigating the acoustic characteristics of oceanic hydrophysics. By propagating acoustic signals through the water, researchers could study ocean-bottom relief structure, the interaction of different water masses, and spatial-temporal variability in a given section of the ocean. From 1960 to 1970, scientists studying acoustics could voyage on *Sergey Vavilov* or *Piotr Lebedev*, research vessels designed especially for acoustic research. These two ships were recently replaced by the Finnish-equipped *Akademik Vavilov* and *Akademik Ioffe*, which will allow for higher-range acoustic studies. Soviet acoustic researchers discovered the underwater acoustic channel in the

Japan Sea (independently of US scientists), performed complex studies of sound propagation over long distances, and examined sound dispersion over the ocean's surface.

The Polygon Strategy

POLYGON studies revealed a new pattern of water movement that came to be known as the long-lived synoptic eddy, which can be thought of as an oceanic cylone.

A new era in Soviet oceanology began in 1966 with the launching of the 6,000-ton *Akademik Kurchatov*, a research vessel outfitted with state-of-the-art technology that allowed for more sophisticated data collection and processing. The launching of several other similarly equipped ships permitted the first tryout of the so-called "polygon strategy" for studying large sections of the ocean. The polygon strategy, formulated by Vladimir Shtockman and his associates at the end of the 1960s, entails continuous collection of hydrological data at many points along the sides of a gigantic polygon. In 1970, *Akademik Kurchatov* and five other Soviet ships took part in POLYGON-70, one of the first oceanic polygon studies. We personally participated in POLYGON-70: Leonid M. Brekhovskikh was chief scientist of the expedition, and V. G. Neiman was a deputy chief scientist aboard.

The POLYGON scientists collected current and temperature data in the tropical North Atlantic around the perimeter of a square measuring 250 kilometers per side. The stationary basis of the experiment, a cross-shaped field of 18 moorings carrying current and temperature recorders at several depths, recorded data for more than six months. This work revealed a new pattern of water movement that came to be known as the long-lived synoptic eddy, which can be thought of as an oceanic cyclone. Further analysis of these eddies revealed that they contain at least 90 percent of the ocean's kinetic energy, and eventually led to a new understanding of the mechanisms of oceanic circulation. POLYGON-70 so convincingly demonstrated the utility of the polygon strategy that numerous polygon studies were conducted in the 1970s and 1980s to study the physical characteristics of large areas of the ocean (see Physical Oceanography: A Review of Recent Soviet Research, page 81).

Significant Soviet oceanological achievements of the last two decades include the discovery of an important structural element of oceanic waters: fine vertical structure of density, temperature, and salinity fields. Soviet scientists A. Monin, K. Fedorov, and V. Shvetsov, through experimentation, defined this oceanic fine and layered structure.

As new scientific problems arise, increasingly advanced research is needed. To modernize the Academy's research fleet, at the end of the 1970s and the beginning of the 1980s, ten ships of three different types were acquired. The three biggest ships are supplied with diving bells and chambers for deep-water diving work. These systems were used to allow scientists to hand-collect biological and geological samples at depths of up to 200 meters in a shelf zone and at the top of seamounts in the open ocean. In 1981, R/V *Akademik Mstislav Keldysh* was launched. Built in Finland, it was the best-equipped ship of its time, complete with an integrated system for automated data collection and processing. In the 1980s, 14 new ships were added to the research fleet of the institutes of the USSR State Committee on Hydrometeorology in order to bolster collection of marine synoptic information. The star of the fleet is *Akademik Federov*, a 16,200-ton icebreaker designed for research work in

polar latitudes. Many of the research vessels are currently involved in the state program "World Ocean," which consists of dozens of basic projects performed cooperatively by scientists from many research communities.

The Growth of Soviet Oceanology

Research institutes, as well as ships, have been added to the Soviet oceanology community over the last four decades. By the end of the 1960s, a network of oceanology institutes stretched across the Soviet Union, including the P.P. Shirshov Institute of Oceanology and the State Oceanographic Institute in Moscow; the All-Union Research Institute of Marine Fisheries and Oceanography in Leningrad; the Arctic and Antarctic Research Institute in Sevastopol; and the Marine Hydrophysical Institute and the Institute of Biology of Southern Seas in Vladivostok. Moscow, Leningrad, and Vladivostok remain the centers of research, with regional outposts in coastal cities.

The institutions have been active in many international research projects. During the International Geophysical Year, Soviet researchers made more than 30 expeditions, accumulating information on world ocean circulation, water chemistry, and other topics at more than 2,500 data-collection stations. Soviet scientists also took part in the International Indian Ocean Expedition from 1959 to 1961, helping to compile an atlas of Indian Ocean characteristics. Since then, Soviet participation in both bilateral and international research projects has continued to grow, organized by national committees with groups such as the Scientific Committee for Oceanographic Research and UNESCO's Intergovernmental Oceanographic Commission. The history of Soviet scientific achievement suggests that Soviet scientists will continue to play a significant role in the international development of oceanology.

During the International Geophysical Year, Soviet researchers made more than 2,500 data-collection stations on over 30 expeditions.

Acknowledgements: *Thanks to Traci Watson, a summer Intern for* Oceanus, *for her extensive work and research on this article. We are grateful also to Henry Stommel, Senior Scientist at the Woods Hole Oceanographic Institution, for his technical assistance.*

Leonid M. Brekhovskikh is Head of the Department of Oceanology, Physics of the Atmosphere, and Geography, and Chairman of the Commission on World Oceans at the USSR Academy of Sciences.

Victor G. Neiman is the Deputy Head of the Department of Oceanology, Physics of the Atmosphere, and Geography, and is also a corresponding member of the USSR Academy of Sciences.

Living Marine Resources

Their Conservation, Rational Utilization, and Management in the USSR and the World

Viatcheslav K. Zilanov

By nature, fishery problems are international. They touch upon the interests of all nations and demand a joint effort to attain the common goals of environmental protection and conservation, optimum utilization, and rational management of renewable living marine resources. Achieving these goals requires continuous, active maintenance of the world ocean's natural resource potential in order to meet the ecological, economic, and social demands of the world community. All states, whether coastal or landlocked, are responsible for the ecological safety of the world ocean and for conserving living marine resources for the benefit of present and future generations.

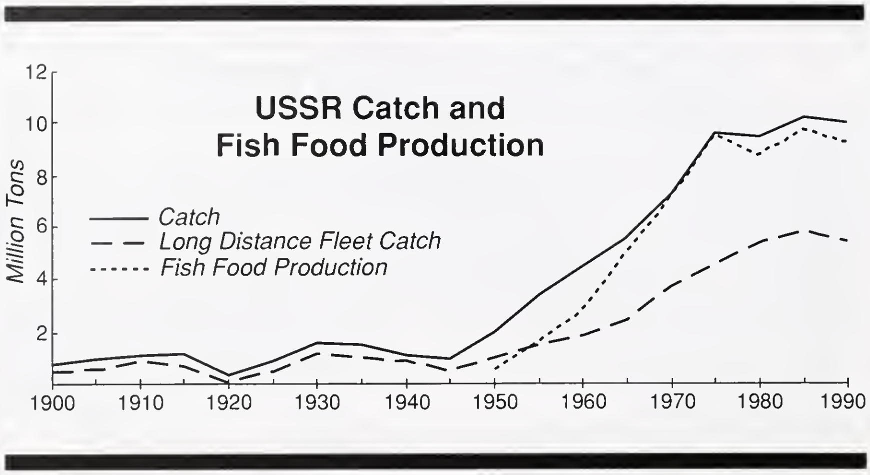
All states, whether coastal or landlocked, are responsible for the ecological safety of the world ocean and for conserving living marine resources.

A Market for Fisheries Products

In the Soviet Union, fish are an important food source. On average, seafood constitutes 20 to 25 percent of the animal protein consumed per capita annually, with higher rates occurring in coastal, lake, and river areas. Annual consumption of seafood increased from 12 to between 17 and 18 kilograms per capita over the last 30 years. (For the US in this same period, annual seafood consumption increased from approximately 5 to 7 kilograms per capita.) In addition, the USSR fishery produces fish meal for livestock and poultry and supplies miscellaneous fish to animal breeders (such as polar fox and mink farmers). Fish is also an important raw material for medical products. The total annual USSR landings of 10.4 to 11.4 million tons are the source of raw fish for all these components of the Soviet economy. Approximately 92 percent of the landings are from seas and oceans, and 8 percent are from inland waters. Up to 5.5 million tons are used for human consumption.

The USSR landings, which constitute 12 to 14 percent of total world landings, have increased significantly following World War II, from 1.1 million tons in 1945 to 11.4 in 1988. A downward trend over the last two years (10.4 million tons in 1990) is due to a number of complex problems facing the Soviet economy, primarily the transition to a market economy and the conditions established under the 200-mile exclusive economic zone (see The USSR and the International Law of the Sea, page 35).

The USSR's fishing industry has prospered in this century. Beginning approximately 40 years ago, total landings, long-distance landings, and fish-food production steadily increased to new, higher levels. Applying scientific principles to future marine resource management could improve these numbers even more.



Robert Bragdon & Jayne Doucette

The long period of high USSR landings is a result of discovery by scientists and exploitation by fishermen of a number of new fishing grounds and fish resources, both in the shelf areas and in the high seas outside the 200-mile zones. These new fisheries include:

- redfish, blue whiting, and mackerel in the North Atlantic,
- horse mackerel and sardines in the South Pacific,
- squid, ice fish, and toothfish in the South Atlantic,
- krill and lantern anchovy in the Southern Ocean, and
- saury, horse mackerel, mackerel, and squid in the North Pacific.

International Fishery Issues

P.A. Moiseyev, a leading Soviet biologist, estimated the potential yield of living resources in the world ocean in 1987 to be 120 to 150 million tons, excluding species of lower trophic levels. (The actual landings in 1988 and 1989 were about 100 million tons.) This estimate appears to agree with conclusions I made in 1986, following my analysis of the exploitation of newly detected living marine resources in various areas of the world ocean. It differs, however, from many recommendations issued by the United Nations Food and Agriculture Organization and by some foreign scientists who take a conservative approach to the utilization of renewable living resources and who consider a landing of 100 million tons to be the upper limit. In my view, current knowledge of world ocean bioproductivity, taking into account well-founded conservation measures and rational utilization of living marine resources, allows an optimistic view of further world-fishery development.

Unlike any other nation in the world, the USSR has as many as 14 adjacent fishing neighbors: Norway, Finland, Sweden, Poland, Germany, Romania, Bulgaria, Turkey, Iran, Korean People's Democratic Republic, the Republic of Korea, China, Japan, and the US. Coordination with these countries is particularly important in establishing measures for conservation, optimum utilization, and management of "straddling stocks," which inhabit or straddle the 200-mile zones of both the USSR and adjacent nations. As a rule, this coordination is carried out by joint fisheries commissions or other bodies established by intergovernmental agreements and arrangements. For example, conservation of bioresources in

the Bering Sea is based on the 1988 USSR-US agreement on mutual fisheries relations. This agreement officially recognizes that a significant portion of living marine resources of the Bering Sea ecological complex is found both within and beyond the economic zones of the two parties, and is exploited by fishermen of both countries.

In addition to improving forecasts, the problems of conservation, optimum utilization, and management of living marine resources in the 200-mile zones of the 15 countries require an international treaty to provide a mechanism for independent monitoring of fisheries and for adopting recommendations that would be compulsory for all resource users. It would set up "confidence measures," including mutual inspection of fishing activities of national fleets in one another's zones. For this purpose, it would be reasonable to establish independent international regional scientific research centers or institutes for:

1) the Bering and Chukchi seas (involving the USSR and the US),
2) the Sea of Japan (USSR, Japan, Korean People's Democratic Republic, the Republic of Korea),
3) the Black Sea (USSR, Turkey, Bulgaria, Romania),
4) the Baltic Sea (USSR, Finland, Sweden, Poland, Denmark, Germany) and
5) the Barents Sea (USSR and Norway).

Each center or institute would be established jointly and equally funded by neighboring states. Scientific staff would be comprised of nationals of those countries, and scientists from other countries might be invited to participate. Such a system of scientifically founded conservation and management of living marine resources would help to build confidence both among neighboring countries and among fishermen.

Problems of conservation, optimum utilization, and management of living marine resources require an international treaty.

Fisheries Protection Through Scientifically Based Management

The USSR places particular importance on the conservation, enhancement, and optimum utilization of anadromous (river-spawning) species, primarily Atlantic and Pacific salmon. The North Pacific contains the world's greatest concentrations of salmon. These are exploited by fishermen of the USSR, the US, Canada, and Japan. Our estimates indicate that Asian and American salmon stocks together could provide some 1 million tons a year, possibly doubling the 500 to 700 thousand tons currently obtained, if the fishery were managed according to the scientific principles of conservation, optimum utilization, and management. This would primarily require suspending salmon drift-net fishing beyond the 200-mile zones and stopping illegal poaching by any means available.

The Soviet Union proposes to ban completely, beginning in 1992, Japanese fishing for salmon that originate in USSR rivers, outside its 200-mile zone in the Northwest Pacific. In fact, scientists and fishermen in the USSR believe that fishing for salmon should be allowed only within 50 miles of the coast, in order to avoid taking foreign salmon.

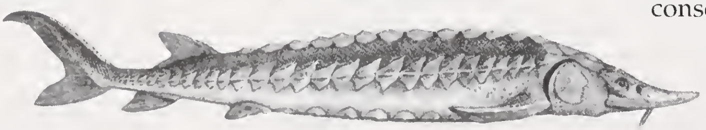
The USSR cooperates with other nations through 12 international fisheries organizations. In these organizations, the Soviet Union always supports all recommendations for conservation of living marine resources based on the best scientific data available. Conversely, those conservation measures adopted through "the voting machine" or on an emotional basis, as is often the case with the International Whaling

Commission (IWC), are not supported by the Soviet Union and are not binding to it. It should be pointed out that, pursuant to the recommendations of the IWC Scientific Committee, the USSR stopped taking blue and humpback whales in the entire world ocean beginning in 1965 and has not engaged in whaling in the Antarctic since 1987. Like the US, the USSR allows whaling in the Bering and Chukchi seas for aboriginal subsistence. In compliance with international law, Soviet scientists study whales throughout the world ocean.

Another important problem is conservation, optimum utilization, and management of sturgeon stocks inhabiting primarily the Caspian, Azov, and Black seas and a number of rivers in Siberia and the Far East. About 98 percent of the world sturgeon stocks are found in the southern seas of the USSR; the Caspian Sea along with the Volga, Ural, and a few other rivers are so far the only waters in which a system to sustain sturgeon stocks at a satisfactory level has been successfully optimized. Hence, fishing for sturgeon in the Caspian Sea was completely banned beginning in the early 1960s (though Iran continues to take sturgeon close to its shores), and fishing in river estuaries is strictly limited, both in terms of volume of landings and length of fishing seasons. Since the development of stock-enhancement biotechnology, 27 hatcheries produce up to 100 million giant, Russian, and stellate juvenile sturgeons annually. This makes it possible to take 18 to 25 thousand tons of sturgeons a year. At the same time, sturgeon stocks have been increasingly affected by pollution of the Caspian, Asov, and Black seas, especially by pesticides, oil byproducts, and sewage. The threat of extinction could become quite real unless this pollution is halted.

Soviet Fisheries Issues

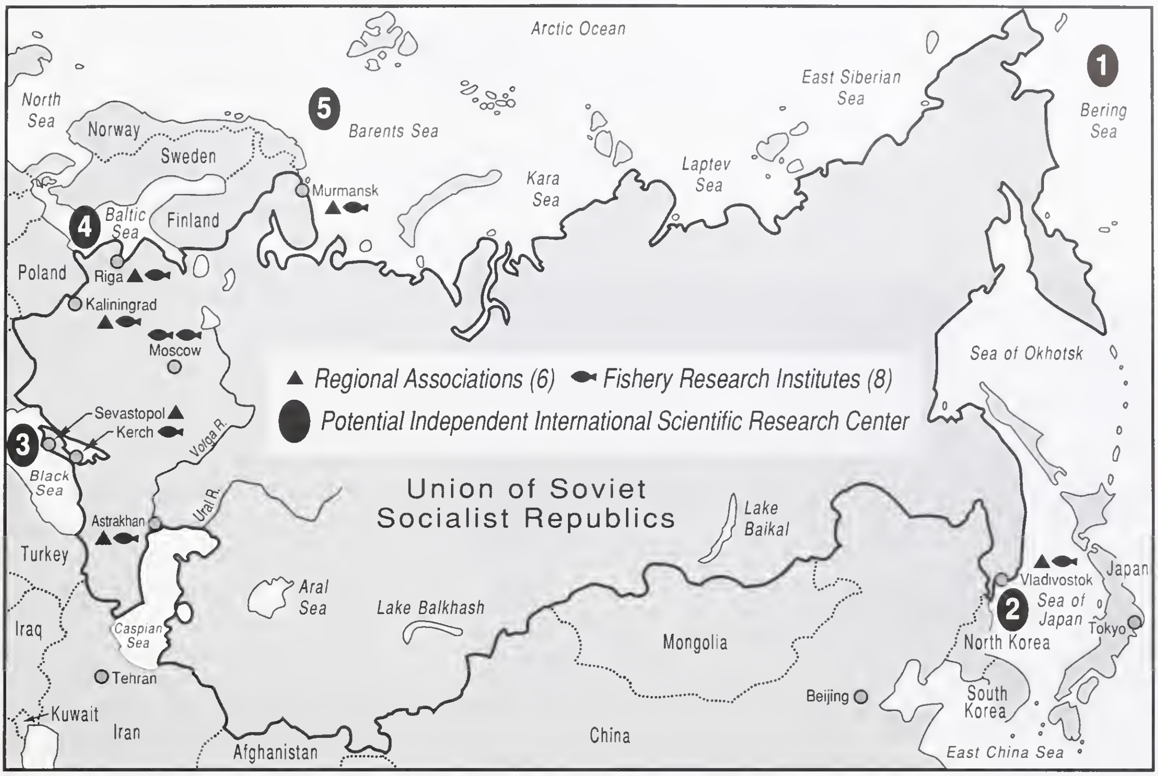
Modern Soviet fisheries operate within strictly defined legislative frames. This is particularly important when restructuring in the USSR demands practical implementation by individual states and separation of the function of the Soviet Union and the republics. Soviet law, especially the USSR constitution, basic water legislation, and the law on animal protection, establishes standards for a wide variety of activities related to conservation, rational utilization, and management of living marine resources. The Constitution stipulates the Law on the State Boundary of the USSR, which establishes fishing regulations within the 12-mile limit, and the Decrees of the Presidium of the Supreme Soviet on the Economic Zone of the USSR and on the Continental Shelf, which defines the rights and duties of the USSR relative to conservation, exploitation, and management of living resources within the 200-mile zone and on the continental shelf. Based on these laws, a number of documents and regulations have been issued that apply to exploration, conservation, and utilization of living resources within the USSR's economic zone, as well as the operation of research and fishing vessels in the world ocean beyond the 200-mile zone.



Sturgeons live in salt water but travel a thousand kilometers or more to spawn in the fresh water of rivers. Adults range from 100 to 215 centimeters long and weigh as much as 280 kilograms.

From *Fishes of the North-eastern Atlantic and Mediterranean*, UNESCO

Responsibility for execution of these laws lies with the Ministry of Fisheries. A special branch of the ministry is responsible for conservation



Author Zilanov suggests that an international treaty might establish regional scientific research centers for the areas indicated by dark ovals. The Soviet regional associations, (triangles) coordinate the activities of area enterprises, cooperatives, and their associations, and the fishery research institutes (fish) study and monitor various aspects of the fishing industry.

and management of the living resources. Fishing, processing, and marketing are undertaken by enterprises, cooperatives, and their associations, and in recent years, joint ventures (foreign-partner purchases at sea of fish caught by fishermen of the country) have been established, and individual users of living resources have also appeared. Cooperatives and other owners of the means of production are now entitled to act independently and to conduct external relations with foreign companies and organizations, including export-import operations.

Regional Associations Coordinate Management and Research

Six large regional associations coordinate the activities of the enterprises, the cooperatives, and their associations. They are based in Vladivostok, Murmansk, Riga, Kaliningrad, Sevastopol, and Astrakhan. Eight fishery research institutes study and monitor biological resources and the environment, project species abundance, and advise on conservation, optimum utilization, and management of living resources. They make annual forecasts of possible yields from 494 stocks of over 150 species of fish, crustaceans, molluscs, and algae. Two research institutes are in Moscow, and the others are located in Kerch, Astrakhan, Vladivostok, Murmansk, Riga, and Kaliningrad. They receive 60 to 70 percent of their funds from the federal budget and the remainder from industry (enterprises, cooperatives, and other organizations) on a contractual basis.

Stock assessment and estimation of total allowable catch (TAC) are made with consideration of the principles of conservation, reproduction of individual stocks, and conservation standards recommended by

international organizations. There is a recent trend toward an ecosystem management approach within the 200-mile zone of the USSR based on multispecies biological models combined with such environmental factors as climatic changes and unusual natural phenomena. TAC predictions and conservation measures are considered and adopted by seven regional (basin) scientific councils, then by the General Coordinating Scientific Council where industry representatives and scientists from all regional research institutes participate. The measures are finally approved by the Board of the Ministry of Fisheries of the USSR.

Lantern nets used for scallop farming are being prepared for use at a Soviet aquaculture facility.

Regional Scientific Fisheries Councils allocate the TAC among the fishery users with final approval of the Ministry of Fisheries. Each user is responsible for fishing within its catch allocation for a particular species and for conforming to fishing regulations. Severe violations of the regulations can be treated as criminal.

Further development of the USSR fishing industry in this decade is primarily dependent upon, as previously, a stable resource base for the fishing industry. The following priorities have been identified for Soviet fishery resources:

1) Further exploration, conservation, optimum utilization, and rational management of living resources within the 200-mile zone and on the USSR's continental shelf.
2) Extensive development of aquaculture and mariculture in inland waters, rivers, ponds, and coastal seas of the USSR.
3) Continued exploration for fishery resources in international waters of the world ocean outside the 200-mile zone.
4) The use of underutilized fish resources within the 200-mile zones of foreign states where intergovernmental agreements are shared.

Another, no less important issue arose recently in our country as a result of the democratization of our society and strengthening of the republics' sovereignty. It concerns distinguishing the rights and duties of the Union and of the individual republics with respect to fishery, as well as other, issues. A new law on conservation of living resources and management of fisheries within the 200-mile zone and on the continental shelf is being drafted to help the USSR play its role in conserving living marine resources for all generations and peoples of the world.

Acknowledgements: *We thank Helen Mustafa of the National Marine Fisheries Service, Northeast Fisheries Center, National Oceanic and Atmospheric Administration, for technical assistance with this article.*

Viatcheslav K. Zilanov is Deputy Minister of the Ministry for Fishing Industry, and an expert on the economic and geopolitical problems of ocean fishing.

The USSR and the International Law of the Sea

Yuri G. Barsegov

Editor's Note: *Until this century, the global law of the sea was relatively simple but stable. It consisted primarily of freedom of the sea for most purposes, including navigation and resource use (primarily fishing) by private, commercial, and military vessels. In the last 50 years or so this has changed. To control the seas near them, coastal states have been constantly reducing the traditional freedom of the seas. The areas controlled have been continually increased in size as well. Many states that previously claimed a small territorial sea around their boundaries, where they maintained exclusive rights while still permitting innocent passage for foreign vessels, now claim large territorial seas plus an expansive exclusive economic zone (EEZ) or exclusive fishing area, where foreign vessels may navigate but may not remove resources.*

This reduction of general freedoms created sharp disagreements between states, resulting in confusion and general instability in the law of the sea. Internationally, attempts to resolve conflicts over territorial seas were made as early as 1930 by the League of Nations and in 1958 and 1960 by the United Nations (UN). Unfortunately, the rapid expansion of international ocean use and new unilateral claims soon made the resolutions from those conferences obsolete. It became obvious that an international law for the oceans, agreed upon by a consensus of the states, would be needed to minimize conflicts between nations and restore stability to the law of the sea.

Towards these ends the UN assembled the Third United Nations Law of the Sea Conference. From 1974 to 1982 the states participating in this Conference negotiated to prepare an extensive international code, titled the United Nations Convention on the Law of the Sea, or UNCLOS. Signed in 1982 by representatives of most countries, the document addressed fifteen major topics and contains 400 articles in almost 200 pages. The US agreed with most provisions, but found the Convention's regime for deep-seabed mining unacceptable; hence the US, along with the United Kingdom and West Germany, did not sign the Convention. Because it is a superpower, the US's rejection of the Convention has weakened the Convention's impact on world ocean law.

Before the Convention can take on its full legal force as an internationally accepted treaty, it must be signed and ratified by at least 60 states. So far only about 40 states, many of them small, developing countries, have ratified. Neither the USSR nor the US has ratified. Diplomatic efforts are continuing to seek a solution. In the following pages, veteran Soviet diplomat Yuri Barsegov explains the history of the USSR's position on the Convention.

An international law for the oceans is needed to minimize conflicts between nations and restore stability to the law of the sea.

Adopting the International Law of the Sea Convention has often been termed the Blue Revolution, and the diplomatic forum from which the Convention emerged, the Third United Nations Law of the Sea Conference, the "conference of the century." This historic work focuses on restructuring interstate maritime relations and establishing a convenient base for legal regulation of all other interstate relations (scientific, technological, social, economic, political, military, and ecological) and activities involved in exploiting the world ocean.

The intent of the Conference was not to codify the existing law of the sea and fill in gaps, but rather to form new rules and institutions to regulate both traditional and modern marine activities and develop them progressively with regard to newly created conditions.

Now the euphoria surrounding the Blue Revolution is over. The political emotions of the Conference are softened, and an opportunity exists to make a sober political and legal estimate of the last ten years of effort by the world community. It is a good time to define the attitudes of states, various groups of states, and the world community as a whole toward UNCLOS.

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A quick adoption of the Convention was eagerly awaited by a majority of the Conference participants. Now, ten years after its triumphal signing in December 1982 by 119 states, the Cook Islands, and the UN Council on Namibia, the Convention is being enforced. What will be the Convention's fate? What are the prospects for the new legal order of the world ocean?

The problems of exploitation of the world ocean are global. The answers depend on all groups of states and on every state taken individually. The USSR is a large maritime nation: It is obvious that a lot depends on our activities and policies.

During the last 70 years, the marine policy of the USSR and the Soviet position with respect to the international law of the sea have changed enormously. This is clear not only from the Soviet attitudes toward the international governing of adjacent seas or straits, but also toward the more general tenets of UNCLOS. Until now Soviet thinking on UNCLOS was dominated by military and political priorities. The Soviet navy's relative weakness created a defensive approach, which expressed itself during the last century in attempts to limit uncontrolled access to adjacent seas. The "closed sea" regime was established, restricting passage through the straits or any effort to establish control over the straits. The history of the Black Sea Straits is characteristic of this approach. The Soviet state inherited this defensive approach from its Tsarist predecessor, and later used it in a desire to "lock itself" within the adjacent seas two ways: by adhering to the idea of a maximum 12-mile territorial sea, and by restrictively interpreting the qualifications of "innocent passage" through territorial seas as "the right of passage through defined corridors only." It should also be noted that during the Cold War, the US and other Western countries continuously pressured the USSR to adopt a three-mile territorial sea.

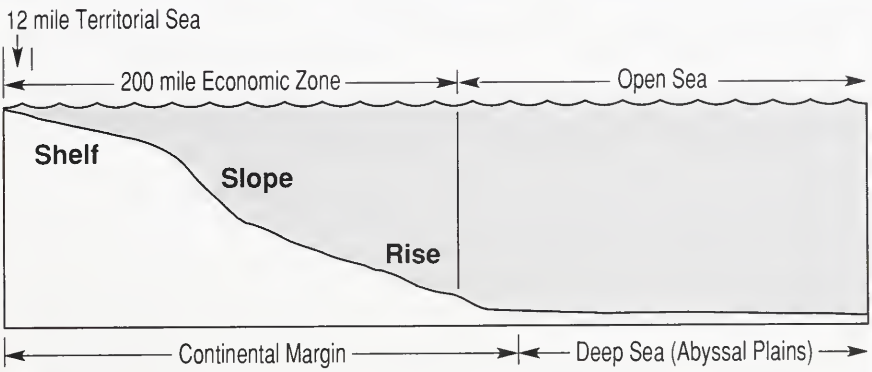
Nevertheless, it is interesting to note that even during times of military and political antagonism between the two superpowers, with regard to the world ocean there are many opportunities for cooperation, espe-

cially in establishing regulations and in maintaining international and legal diverging interests—even within the sphere of naval navigation. Now, the antagonism of the Cold War is (almost) removed. Presently other perspectives emerge, based on a respect for the universal interests of humanity.

The Soviet Realm of Interest in UNCLOS

In considering the factors that formulate the USSR's marine interests, it is incorrect to stress only military and political reasons. The country's geographic position, with coasts on both the Atlantic and Pacific oceans, creates an important role for merchant shipping. Particularly since World War II, seaborne trade and merchant shipping interests have motivated the USSR to strengthen freedom of navigation in the high seas, including the EEZ and the straits used for international navigation. Seaborne transportation is the most important type of commodity transport between the USSR and other countries. More than three-

Jayne Doucette



Recent Law of the Sea negotiations permit nations to restrict access to seas adjacent to their coasts. Up to 12 miles may be claimed as territorial sea, where the claiming nation may demand exclusive rights. Continuous with the territorial sea, up to 200 miles may be claimed as an exclusive economic zone or EEZ, where the nation maintains sole fishing and resource rights. In both of these zones, navigation access for friendly foreign vessels is permitted.

fourths of all Soviet foreign trade cargo is transported by sea. Soviet marine transport comprises more than 60 percent of all foreign trade transportation, and vessels flying the Soviet flag visit more than 1,400 ports in 113 states in the world.

Economic considerations related to postwar development of the USSR's modern merchant and long-distance fishing fleets created a negative Soviet attitude at the beginning of the Third Law of the Sea Conference toward the establishment of 200-mile territorial seas. The USSR was firmly attached to the convention of freedom of fishing beyond the limits of the 12-mile territorial sea. However, political considerations—the desire to promote positive relations with developing countries—resulted in concessions on the establishment of 200-mile economic zones. Gradually, the USSR reoriented its fishing and adjusted relations with the states in whose zones it had traditionally fished. The Soviet Union thus changed its attitude toward the EEZ, and eventually even came to appreciate the benefits of this zone of functional jurisdiction.

The USSR's desire to prevent the military use of the seabed by its potential enemies, the US and NATO, formed the basis of the Soviet position on the regime to govern seabed uses beyond national jurisdiction. The USSR's position in the discussion soon reflected its demand for resources and its readiness to develop deep-seabed resources. Its position coincided in some regards with those of developed countries and in other regards with developing countries, making the USSR a stabilizing center in the discussions.

The USSR occupied a bargaining position on the question of the legal outer limit of the continental shelf, which was one of the important Conference issues. Being against "creeping jurisdiction" (the gradual extension of coastal state control via unilateral claims), and considering the interests of coastal states and the international community as a whole, the USSR aspired to find a compromise. Hence from time to time the USSR presented proposals describing various distance criteria, based on physical and geological factors. A proposal introduced early on by the USSR combined a depth criterion, the 500-meter isobath (the geomorphological edge of the continental shelf in most places), and a distance criterion, up to 200 miles off the coast. After this official proposal was rejected, the Soviet delegation put forward an unofficial proposal setting the limits of the continental shelf at a fixed distance beyond the 200-mile economic zone. The Soviet delegation examined the possibility of setting the continental shelf limits according to the outer edge of the continental margin, but not farther than 100 miles from the outer limit of the 200-mile EEZ, or 200 miles from the baselines from which the territorial sea is measured but where the continental margin doesn't extend that far. Taking into account the interests of states having a broad shelf, the USSR made clear its readiness to recognize the preferential right of a coastal state to acquire, research, and develop seabed sites adjacent to its shelf, even though these sites may extend into international area recognized as the "common heritage of mankind" or open sea.

The USSR's interests in world ocean law are part of those of the whole of mankind.

A Changing Perspective

The Soviet people have gradually become aware of the legalities of the international law of the sea. Linking ourselves with the world community and its interests, we participate by searching for mutually acceptable solutions and compromises among nations. Despite the formal international character of the USSR's official communist ideology, an authentically humane and civilized approach has emerged. Long hindered by egocentric political considerations that determined state policy, we now understand the USSR's interests in world ocean law are part of those of the whole of mankind, and we reject the narrow class approaches that were based on the priority of policy over law.

This does not imply, of course, any rejection of our national interests, but rather an understanding of the need to harmonize national and international interests and to submit them to common interests of the international community. This process is very complex, difficult, and thus, prolonged. It supposes, first, an accurate estimate of the interests at stake, and second, a readiness to compromise and concede when necessary. Realism is required both on the individual (national) and on the

collective (international) levels. In this respect, the Conference has been educational for all the states involved, including the USSR.

Until recently Soviet diplomats were evidently flattered that the altruistic distributive principle of an ideal communist society—from everybody, according to abilities, to everybody, according to demands—was employed by developing countries to resolve issues of deep-seabed resource exploitation. We now realize, however, that this principle does not work. On the contrary, it has brought us to complete economic disorganization, all the more because financial and technological means belonged to states that did not share the communist ideology. Moreover, revisions in estimates of mineral and other raw material deposits, and deterioration of metal-market conditions as expressed by a sharp price decline, served to further aggravate the distortions inherent in the deep seabed regulations. Soviet specialists understand the need to make definite corrections in that system aimed toward harmonizing the interests of different groups of states and the interests of every individual state in an effort to revive the Convention.

UNCLOS: A Package Deal?

The Convention offers a stable, international legal order. There is a strengthening trend to consider the Convention common law, even if it does not come into force or is ratified by only a limited number of states. When one considers the future of world ocean law if the Convention does not come into force and effect, or is ratified by a limited number of states as common law, the need is clearer still.

From the initial sessions of the Conference, the USSR supported the political and legal "package" principle, which did not allow a selective approach to various provisions of the Convention. Now, as earlier, the Soviet doctrine considers preservation of the "package" as reinforcing the legal order. However, Soviet analysis also reveals that the actual practices of states are far from being in line with the criteria of the customary rules of international law, such as the existence of a universal (i.e., uniform, active, and continuous) behavior that allows conclusions to be drawn relating to a state's displayed consent. In view of this, we have reservations as to how legally binding the Convention may be if the new rules and institutions are merely approximated by some states.

While the chances of rapid ratification and enforcement of the Convention are decreasing, in the interest of the world ocean's legal order and stability it is essential that Convention regulations be enforced by the authority of customary law. At the very least, the broadest areas of coinciding interests should be singled out and enforced. The favorable international political climate that now exists makes this minimal request reasonable. *Perestroika* plays an important role in this process. Should the development proceed in this way, the Convention's adoption and signing by more than 120 states might be considered an *opinion juris,* or an expression of each state's will to attach the practice of force into customary law regulations.

When one considers the future of world ocean law if the Convention does not come into force and effect, the need is clearer still.

Questions for the Future

In discussing possible Soviet participation in development of an international law of the sea in the 21st century, it is impossible to avoid the

question of the future of the USSR itself. Will the USSR be preserved as a federal state with its marine interests, rights, and obligations? Or, will those interests, rights, and obligations be passed to the republics that are current members of the Union, seven of which are coastal and nine, landlocked? If legal capacity is given to those republics that now have autonomous status, the number of landlocked republics may increase. In this situation, even if the Union is preserved, a new set of requirements emerges, including the need to designate which areas are within the functional jurisdiction of which states, especially with regard to the continental shelf and the 200-mile EEZ.

These issues are complicated and may soon become urgent. We are attempting to forecast solutions, but are impeded by the current status of the Convention. Many disagreements between the USSR's constitution and the declarations of national sovereignty of various federations and between the Union and the the republican legislation are escalating. The new Union Treaty does not address questions of the legal status, resource use, and delineation of territorial waters, EEZs, and the continental shelf. Economic activities in these areas are expected to be administered by the state in a way conducive to transfer to a market economy.

A global law of the sea is vital to the interests of all nations, both coastal and inland.

A global law of the sea is vital to the interests of all nations, both coastal and inland. The current interim policy, whereby the Convention is followed for the most part but not actually ratified, does not offer the long-term stability that we need. While not perfect, a widely ratified Convention could ensure that all nations comply with basic rules and obligations regarding navigation, pollution, and fishing, thereby lessening disputes; invoking mandatory third-party dispute settlement could further help to reduce disagreements to a manageable level. The effects of a widespread ratification of the Convention are far reaching: By making ocean law more predictable, order will increase and common values such as human rights and environmental protection will be easier to promote. In the interest of our common welfare, we continue to search for solutions and compromises that favor the widespread ratification of the United Nations Convention on the Law of the Sea.

Acknowledgements: *We thank James M. Broadus, Director of the Woods Hole Oceanographic Institution's Marine Policy Center, for his technical assistance with this article.*

Yuri G. Barsegov is a Professor of International Law and a member of the United Nations International Law Commission. He is Head of the Ocean Development and Environment Department of the Institute of World Economy and International Relations of the USSR Academy of Sciences.

Soviet Polar Research

Arthur Chilingarov

Polar research is given high priority in the Soviet Union: Almost half of the Soviet territory lies within or adjacent to the Arctic. Understanding polar natural processes will help answer scientific questions and solve global problems. Polar regions are also important to the Soviet economy; development in far northern areas, and particularly the creation of many industrial centers 50 and more years ago, as well as the later discovery of oil and gas deposits on the arctic shelf, all require a dependable northern sea route. Life and travel in the Arctic depends upon thorough knowledge of weather and ice conditions.

At the opposite pole, regular Soviet expeditions to Antarctica began 35 years ago with preparation for and execution of the International Geophysical Year. Since then, there has been a Soviet Antarctic Expedition each year. The USSR was one of the first 12 nations to sign the Antarctic Treaty in 1959. Applying to the area south of 60°S latitude, the treaty provides for scientific freedom of investigation and the exchange of data pertaining to the Antarctic region, and prohibits military operations in that area.

Arctic and antarctic research is coordinated by the USSR Commission for the Arctic and Antarctic, which is headed by a deputy prime minister. The commission involves the work of many research institutes and their parent ministries and state agencies, and consists of numerous

US Soviet Embassy

A jubilant party from the nuclear icebreaker Sibir *danced around the top of the world upon reaching the North Pole in 1989.*

ministry and agency administrators as well as the Russian Federation Council of Ministers. Major polar research projects are usually included in the long-term State Program for World Ocean Research, which guarantees financial support from the government, even in times of economic crisis. The USSR Committee for Hydrometeorology is responsible for organizing and conducting polar scientific research. Its leading research institute is the 70-year-old Arctic and Antarctic Research Institute (AARI) in Leningrad.

Arctic Research

Successful arctic ice forecasting dates to 1932 when V. Ju. Vize forecast the general ice cover in summer arctic seas in preparation for the successful voyage of the steamship *Sibirjakov* from its home port in Archangelsk to the Bering Strait. This journey proved the possibility of a northern sea route for regular navigation. (The next attempt the following year failed, however, when the transport ship *Cheluskin* sank.) Today millions of tons of cargo travel this route annually in trips lasting 100 to 105 days. In a dramatic extension of this route in 1977, the nuclear icebreaker *Arctica* reached the North Pole, and in 1987 another nuclear icebreaker, *Sibir*, carried a large scientific party to the Pole. Knowledge gained from these and other excursions have resulted in such achievements as designs for the world's most powerful icebreakers, hydrometeorological and geophysical forecasts for arctic regions, navigation charts, and practical techniques for travelling in sea ice.

US Soviet Embassy

Researchers at a drifting ice station prepare to transport cargo.

Numerical methods for calculating sea-ice distribution and for forecasting sea-ice conditions are now routine. Long-range forecasts cover periods of one to four months, and there are short-range forecasts for four-to-eight and one-to-five days. These methods have been shown to be 80 to 90 percent reliable. In addition, meteorological forecasts that predict atmospheric pressure, air temperature, and wind speed aid arctic navigation. Based on a technique developed by T.G. Vangengeim that uses macrocirculation features, long-range forecasts are issued ten-to-twelve and three-to-five months in advance, and there are three-day and eight-to-ten day short-range forecasts.

The arctic ice cover dictates a need for specialized methods of conducting research. These include the following approaches.

Drifting ice stations. The USSR established the world's first drifting ice station in 1937 with a crew of four men. Since 1954, two Soviet drifting stations have usually worked simultaneously, and a total of 31 have been established. The scientific staff changes annually, and evacuation is possible in emergency situations. The longest lasting ice station drifted

for eight and one-half years (from 1973 to 1982), and covered a distance of 17,000 kilometers, travelling an average of 5.4 kilometers per day.

High-latitude air expeditions. Each year when the drifting ice stations are restaffed and resupplied, hydrological investigations are conducted using the resupply aircraft. One of these expeditions proved 40 years ago that the bottom of the Arctic Basin is not a deep-sea plain but rather a mountainous terrain. This is considered one of the greatest geographical discoveries of the 20th century.

Observation stations. A network of more than 100 arctic stations and observatories situated on the Soviet arctic coast and islands makes meteorological, aerological, solar heating, hydrological, geophysical, and sea-ice observations, and monitors pollution.

Research vessels. During the short summer season, smaller research vessels operate in the Barents, Kara, and Chukchi seas while larger vessels ply other polar areas. A group of small vessels, known as the "ice patrol," was a major source of information on the arctic hydrological regime until its use was discontinued recently.

Satellites. Weather satellites have been important to arctic research. The *Meteor* series of satellites, carrying television and infrared instruments, as well as the *Ocean* series, equipped with sidelook radar and other radiophysical instruments, are used largely for operational purposes.

Automated ice stations. Designed at AARI, these stations are being tested for deployment on drifting sea ice to transmit air temperature, atmospheric pressure, and location via satellite.

Automated ice-information system for the Arctic. For this system, data is collected from all the sources listed above as well as from regional arctic branches of the Soviet weather service. It is integrated into an ice map for arctic seas and used for meteorological and ice forecasting.

The practical work of AARI scientists includes helping to route ships and convoys for marine operations in the main northern ports of Dikson, Tiksi, and Pevel during the summer arctic navigation season.

Many arctic scientific problems are addressed by Soviet scientists. A few of them are summarized below. Other topics of research include ecosystems, water resources, climate change, the Earth's lithosphere, and resource exploration.

Vladimir Volkov

A hole in the ice serves as laboratory for scientists at a drifting ice station.

Sea-ice physics and mechanics. Both laboratory work and fieldwork are under way on the dynamics and the spatial and temporal variability of the ice cover, as well as its interaction with the atmosphere, ocean, coast, and engineered structures. There are studies of icing processes and development of remote methods for measuring the ice cover and its characteristics. Using ice for constructing buildings, moorings, and artificial islands is also being explored.

Interaction between ice and ship. The world's first ice-testing basin was

built at AARI in 1955 to help develop design characteristics and certification standards for icebreakers and ships that operate in icy conditions.

Arctic oceanography. Soviet scientists undertake comprehensive studies of the arctic seas, often using the Norwegian and Greenland seas for on-site studies. Because of the severe climate, observations are substantially supplemented with numerical modelling of oceanographic processes. There are studies of water masses, currents, sea-level fluctuation, tides, and winds. Work on ocean/atmosphere interaction is aimed at understanding short-term climate variability and contributing to long-term weather and climate forecasting. Upper atmosphere geophysical studies concentrate on magnetic disturbances, modelling the electron concentration in the auroral zone, and analyzing the magnetosphere to enhance radio communication reliability in the Arctic. Magnetic, radiometric and ionospheric observations are based at five sites in the Soviet Arctic (Amderma, Dikson, Tiksi, Uelen, Cheluskin Cape, and Kheis Island), and there is a chain of magnetic and radiometric stations in the Kara Sea.

Arctic ecology and pollution. Soviet arctic air pollution is caused by pollutant transport from the industrial regions of Europe, Asia, and North America. Local pollution sources include the mining, steel, and oil and gas industries as well as transportation. River runoff also contributes pollutants in the summer and autumn. Arctic ecology is monitored by a network of land and marine stations located in towns and at industrial enterprises, and also by ships and aircraft.

Polar medicine. Physiologic, psychologic, and hygienic research are undertaken in both the Arctic and the Antarctic. Manuals and recommendations are developed to help solve the problems of human adaptation to life and work under the stressful climatic conditions of polar regions.

R. Denisov

Among many polar accomplishments, Author Arthur Chilingarov was director of the 1987 Sibir *expedition to the North Pole. As winner of the Soviet State Prize, he is known as a "hero of the Soviet Union."*

The USSR has formal bilateral agreements for cooperative Arctic research with Canada and Norway, and participates in several relevant bilateral agreements with the US, including those on environmental protection, oceans, and science and technology. In December of 1988, Leningrad was the site of the first conference of subarctic countries on coordination of research. The Soviet Union is a founding member of the International Arctic Scientific Committee, which was established in August 1990. The USSR also took an active role in the Intergovernmental Conference on the Environment of the Arctic in June 1991.

Antarctic Research

More than 20,000 Soviet people have participated in Antarctic expeditions over the past 35 years. Of these, some 8,000 have overwintered, and the rest have worked as seasonal staff or crew members for ships and aircraft. Nearly 1,000 have travelled by tractor-hauled sledge from the Mirnyy station to work at the Vostok station located in central Antarctica. The USSR operates six antarctic stations, more than any other

country. Molodozhnaya is the meteorological center and the main base of the Soviet Antarctic Expedition. Other stations include Mirnyy, Novolazarevskaya, Progresso, Vostok, the island station Bellingshausen, and a summer station, Banger Oaziz. In addition, 20 coastal stations operate on an occasional basis.

Staff and cargo travel to Antarctica aboard several research vessels (*Academician Fedorov, Mikhail Somov, Professor Vize*, and *Professor Zubov*). Since 1980, large cargo aircraft, currently the IL-76 TD, have also been employed. AARI specialists developed construction techniques for ice runways that can support these and other heavy aircraft. These runways were built at the Molodozhnaya and Novolazarevskaya stations.

V. Chistiakov

Molodozhnaya is the base station for the annual Soviet Antarctic expedition. The USSR operates seven of the some 40 permanent antarctic stations established by 24 countries.

The rich Soviet antarctic science program is in its 36th year. Studies have included solar heating, aerological and ozone observations; geophysics (geomagnetic, ionospheric, and seismic observations); glaciology; marine biology; oceanography; and polar medicine. Environmental monitoring and aerogeophysical work over a 150,000-square-kilometer area are also included in the program. One of the expedition's charges is to provide fishing vessel operators and aviators with hydrometeorological information.

The USSR published the first antarctic atlas in the 1960s, and the second edition is now being prepared. The USSR cooperates with other nations on antarctic research and logistics. For example, in early 1991, the changeover of Vostok personnel was carried out by a US LC-130 aircraft; in return, the US will receive rapid access to new cores recovered by Vostok station's long-term ice drilling program, and Soviet specialists will assist with construction techniques for the annual rebuilding of the US McMurdo station ice runway. Plans are also well advanced for a 1992 USSR/US drifting ice-research station for the western part of the Weddell Sea.

The Antarctic Treaty designates the area below 60°S latitude a zone of peace and encourages scientific investigations and international cooperation. The Soviet Union is proud to work along with other nations in this unique, gigantic international laboratory for the benefit of world science.

Acknowledgements: *We are grateful to Jerry Brown, Head of the Arctic Staff at the Division of Polar Programs, National Science Foundation, for technical assistance with this article.*

Arthur Chilingarov is Deputy Chairman of the USSR Committee for Hydrometeorology, well known in polar research, and winner of the Soviet State Prize for his work on ice navigation.


Arctic
Norwegian Sea
North Sea
Barents Sea
Kara Sea
Norway
Sweden
Finland
Murmansk
Baltic Sea
Poland
Riga
Leningrad
Arkhangel'sk
Kaliningrad
Prepyat R.
Moscow
Dnepr R.
Odessa
Sevastopol
Yalta
Volga R.
Union of Soviet S
Black Sea
Kerch
Ural R.
Astrakhan
Turkey
Aral Sea
Lake Balkhash
Iraq
Caspian Sea
Kuwait
Iran
Persian Gulf
Afghanistan


an
East Siberian
Sea
Anadyr
Bering
Sea
Magadan
Tiksi
Kamchatka
R.
Sea of Okhotsk
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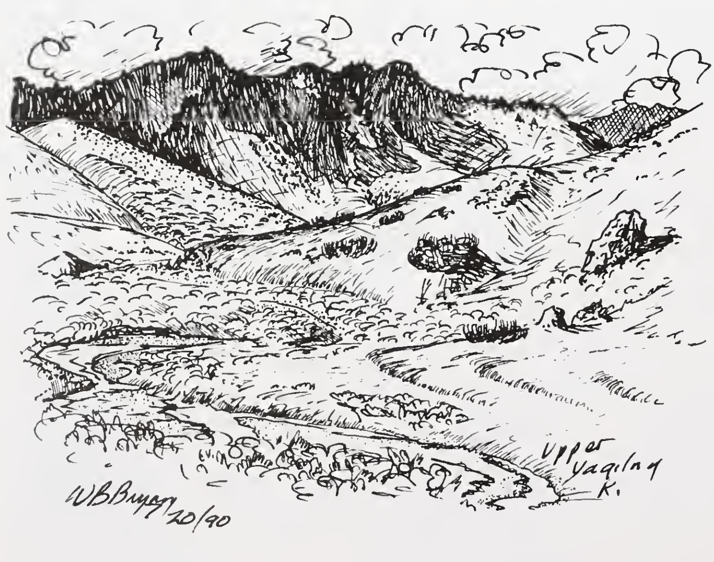
Khabarovsk
Lake
Baikal
Japan
Vladivostok
Sea of
Japan
Mongolia
North Korea
South
Korea
hina
East China Sea

Exploring Pacific Seafloor Ashore: Magadan Province, USSR

Wilfred B. Bryan

I climbed a short, steep track to the top of a rocky knoll, where the view opened to the west. Bright flashes of afternoon sun traced the upper reaches of the Yagilny River. Farther up the valley, the river disappeared into a rocky gorge below a wall of jagged peaks. Through the high pass at the head of the valley, silhouettes of other distant peaks shaded from pale blue to dark violet under low clouds. Anatol Stavsky, leader of our expedition, pointed to another low knoll about a mile to the southwest. "Six years ago I camped in that place. At that time I never dreamed I would be back here with international group." Our tents, pitched below us at the base of the rocky knoll, were sheltered from the easterly gales that would blow up this valley by a low line of scrubby alders growing along a dry creek bed.

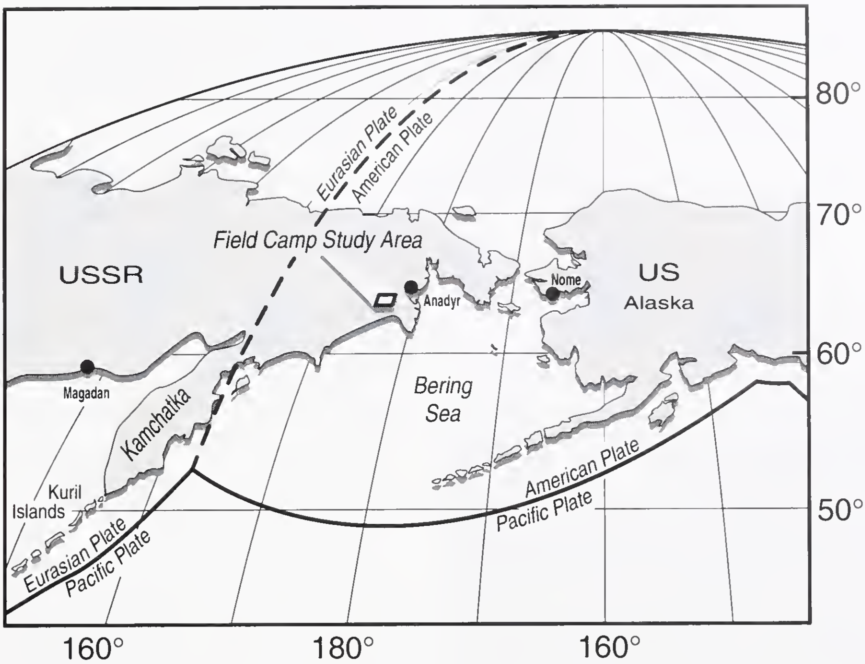


A drawing from Bryan's field notebook pictures the upper Yagilny River in the Korijak Range of far eastern USSR.

Anatol went to attend to camp business, and I remained a while longer on the knoll, watching the patchwork of light and the lengthening shadows. Like Anatol, I could hardly believe the recent rapid change of events that had brought us together in such a wild and unlikely place, in the heart of the Korijak Range in the Soviet far east.

For several years I had indicated to Russian colleagues my interest in visiting geological locales along the Soviet Pacific coast. Here, the Pacific seafloor plate has been colliding with the continent of Asia for at least

Jayne Doucette



150 million years. A conspicuous consequence of this convergence is the vast line of volcanoes that runs from Japan through the Kurile Islands, onto the Kamchatka peninsula, and then across the southern edge of the Bering Sea to Alaska. But this is only the latest manifestation of the intense, continuing conflict between these plates. The volcanoes grow where the Pacific plate is at last forced to bend and descend beneath the edge of the continent, which acts like a titanic bulldozer moving across the Pacific seafloor. The process is neither simple nor orderly; periodically the Pacific plate buckles and breaks, and large fragments are thrust up onto the continent instead of being forced under it. The remnants of oceanic volcanic islands are also caught in this titanic collision, some forced under the edge of the continent, others thrust up onto its edge.

As this debris accumulates in front of the continent, the Pacific plate may be forced to bend in a new place farther seaward, and a new line of volcanic islands forms. Eventually, the remnant of Pacific plate trapped behind these islands buckles and collapses like an accordion, and the arcuate line of volcanic islands (island arc) also may be forced up onto the growing pile of debris at the continental margin. Having spent much of my life studying the Pacific seafloor and its volcanic expressions, I was curious about the ultimate fate of these features.

Late in February 1990 a Telex message from the Ministry of Geology in Moscow invited me to a "geodynamic field seminar" in the Korijak Range in July. The Korijak Range runs northeast through the northern part of Kamchatka into Magadan, and then curves east out into the Bering Sea. I could not imagine what form a "seminar" might take in such a place. The brief message said there would be "excursions on foot and by helicopter," which seemed reasonable enough; the nearest (and only) city of any consequence was Anadyr, which I knew as a major Soviet military air base. I was told that I would have to fly to Anadyr, but after that all transportation and accomodation would be provided.

"Here we are on North American plate," Dodonov says. He smiles. "Until two years ago we were not allowed to say that."

Photos for this article are mostly by Wilfred B. Bryan.

I soon learned what a huge place the Soviet Union is! Aeroflot in New York could not give me any information about internal flights in the Soviet Union, and said that in any case Anadyr was a "closed" city and it would not be possible to go there. But I could fly to Khabarovsk from Japan on Aeroflot; my map showed Khabarovsk to be nearly 4,000 miles from Anadyr, although it is near the Pacific coast of the Soviet Union. Then Aeroflot discovered that they could fly me from Moscow to Magadan, only 1,500 miles from Anadyr. Finally, at the end of May I received another brief Telex: "Fly to Khabarovsk on July 9; we will meet you." By some miracle my visa arrived at the end of June, and on July 6 I was flying to Tokyo, wondering what lay ahead and who my companions would be.

Bryan, outfitted in camp-issue boots, takes a breather on Ugrumaya (Gloomy) Mountain.

At Khabarovsk, Immigration and Customs procedures were slow but routine. No one seemed surprised or concerned that I was going to Anadyr. Anatol was there as promised. We were soon joined by Akira Ishiwatara from Kanazawa University in Japan. We learned that we were the only participants from outside the former eastern bloc countries. The other non-Russians were from Poland, Romania, Bulgaria, and Czechoslovakia. Outside the airport terminal we were accosted by an Intourist man with a very American-sounding accent:
"This way, this way! The Intourist bus is over here."
Anatol looked annoyed. "These men are with me."
"Why, you speak Russian just like a Russian!"
"I am Russian, you idiot—leave us alone!"
After a few more friendly exchanges of insults, the Intourist man walked off, satisfied that we were in good hands. At that point we left the predictable world of tourist Russia for a Russia that had been closed to outsiders for 40 years.

As we landed at Anadyr late in the afternoon, the prospect of reaching our camp did not seem good. Clouds hung low and a persistent drizzle forced us to huddle in the small, jeeplike vehicle that met us at the terminal. Then suddenly we were off, bouncing along a rough track to another part of the field, where a large Aeroflot helicopter was waiting. The pilot assured us that conditions at our camp were favorable. We would soon learn that weather in this region could change quickly, and varied drastically from one area to another.

Our flight took us south over seemingly endless tundra, marked by literally thousands of lakes and sinuous rivers. Ahead through the mist we had rare glimpses of a ragged mountain range. To my surprise, we passed towers with the unmistakable shape of oil-drilling rigs on both

sides of the helicopter. I was not sure I was supposed to have seen these. One of the Russians was amused at my timid question. "Oh yes, is much petrol down there. Maybe someday we sell to American company."

Finally we began to climb over low, barren hills, then more steeply over sharp ridges. We turned to follow a river course between ridges capped by fantastic pinnacles that looked like a collection of grotesque statues. Below, a huge herd of reindeer, startled by our noisy craft, swirled in a magnificent living pinwheel as they sought to escape the din. Then we entered a wider valley, and a tent village appeared on a broad terrace above the river. The helicopter settled into a small clearing and we were "home."

We were issued sleeping bags, cots, and even a pair of large Russian boots that we were urged to wear in place of the standard European mountain boots that we "foreigners" had brought. There were brimmed hats with insect screening to fend off the clouds of mosquitoes that surrounded us, and a can of very effective insect repellent for hands and ankles. Akira and I would share a tent equipped with a small wood stove that would provide welcome heat when the chill winds descended from the peaks. Akira brought mosquito coils, which kept our tent insect-free, much to the amazement of the Russians. Later, we discovered that this Japanese "magic" would keep our dining tent free of the pests as well.

Plate tectonics has been the framework for interpreting marine geology and much of the geology of continental shelves and margins in North America and Western Europe at least since the late 1960s. But the "iron curtain" kept many Soviet geologists isolated from these concepts and from much of the evidence on which they were based; so-called "fixist" views, which maintain that oceans and continents have always been in their current positions, dominated much of Soviet geologic thinking.

Field party members gather near the tents of the first camp.

However, geologists working in the Korijak Highlands (part of a region they call Chukotka) recognized anomalous relations that could only be explained by major lateral crustal movements. For example, paleomagnetic polarities show that the Siberian platform has been located near the Arctic Circle for the past 150 million years, but rocks along the margin of the continent contain younger fossils, such as coral, that could only have lived in subtropical oceans much farther south. Also, paleomagnetic polarities in volcanic rocks associated with these fossils indicate eruption at latitudes of 20 to 30 degrees north, and compositions of some of the volcanic rocks are typical of oceanic islands such as Hawaii. Many other sedimentary and volcanic rock lithologies and associated fossils are types or species typical of deep-ocean

basins rather than of shallow continental margins.

These oceanic rocks are organized into discrete mappable units, or "terranes," separated by major discontinuities in age, lithology, or structure that imply they have evolved as separate units. Sedimentary rocks overlying these terranes or in marginal depressions between them become progressively younger toward the coastline. All of these facts led to the inescapable conclusion that these terranes had originally formed as volcanic islands, island arcs, or deep seafloor, and once were much farther south than their present position. They appear to have been accreted, in successively younger belts, to the Asian coast now bordering the Soviet provinces of Kamchatka and Magadan.

Over the past 20 years, similar terranes have been recognized along the coast of western North America and Alaska; most of Alaska appears to be composed of accreted terranes transported from the south. In effect, as the Pacific seafloor has moved to the north and west, the edges of the continents have behaved much like the blade of a giant bulldozer, scraping off the upper levels of the oceanic crust and many of the high-standing islands, which pile up in row after row of jumbled, fractured blocks. These "rows" now take expression in successive mountain ridges that parallel the coast of the Bering Sea and make up the Korijak Highlands.

"The terrible machina" (above) and helicopters (right) were the principal means of transportation for the field party, other than feet.

As one of a group of geologists from the Soviet Ministry of Geology assigned to map geology and mineral resources in the Korijak Highlands, Anatol was impressed by evidence favoring an oceanic origin, transport, and accretion of the terranes, a concept totally consistent with the direction and extent of Pacific plate motions deduced from many marine geological studies by American, Japanese, and European researchers. He also recognized that few places in the world were better suited to demonstrate the consequences of terrane accretion; in 1989 he suggested to his superiors that a "field seminar" be held in the Korijak Highlands to permit other Soviet and selected foreign geologists to see the evidence. "It will never work," he was told. "You will not be able to take foreigners there, and even if you do, they will not be able to tolerate life in the camps." But Anatol persisted, and in early 1990 the invitations went out.

→ → → → →

Akira and I were initially nervous about taking pictures and rock samples in this "closed territory." Anatol was surprised when we asked if these things were permitted. "Of course it is OK." He said we were supposed to have received maps and other detailed descriptions of the area before the trip, but a paper shortage in Moscow prevented this. To compensate, we were invited to photograph geologic and topographic maps hung on the walls of the dining tent. Even the Czechoslovakian geologists were surprised; one commented to me, "We are like spies!"

Finally on July 12 we were ready for our first major excursion. We boarded a tracked personnel carrier, which jerked and jolted up the river valley, flattening alder scrub as it went. Anatol called it "the terrible machina." All went well until a particularly violent jolt brought it to a stop, and we all got out to stretch while repairs were made. Already sore and bruised, Akira suggested it might be easier to walk. Antony (Tony) Tokarski, from Poland, viewed the vehicle sadly. "Is Swedish concept, Russian materials, and Polish organization." Clearly, in his view, this doomed it to failure.

Bryan's tentmate, Akira Ishiwatara of Kanazawa University in Japan, cools off near Ugrumaya Mountain.

Repairs were made, and we moved on to our scheduled stop. We spent the rest of the day repeatedly fording a swift, frigid river and climbing up and down its banks to look at a sequence of bedded cherts, volcanic tuffs, and sedimentary rocks, all of which appeared to be of deep-sea origin.

This first excursion lent credibility to the concerns about our ability to "survive in the camps." Excerpts from my diary tell the tale.

July 12: Dinner tonight is stew and noodles, borscht, and fresh bread—very good. Only problem is all the dead mosquitoes in the stew.

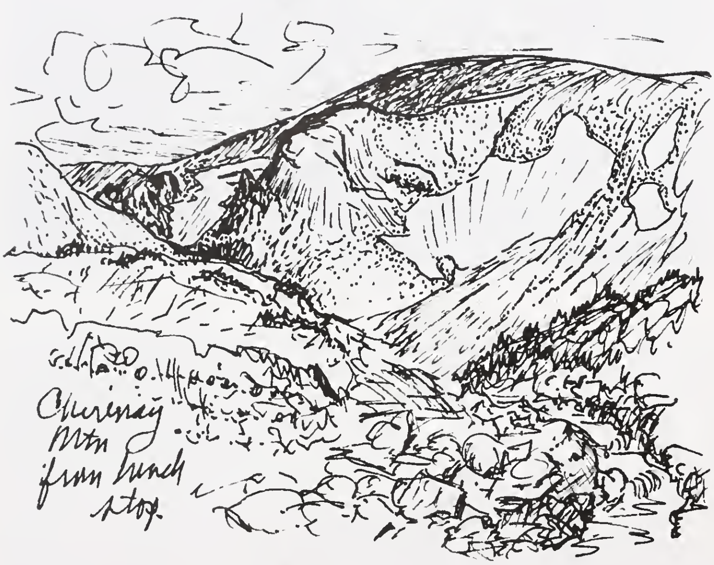
Akira and I are both very tired tonight; many aches and pains. He says, "We have survived two days. Only ten times as much to go." We discuss the rigors of the fieldwork and camp living and note that many Americans and Japanese would not or could not cope with this life and the food. Later we discuss this with Stavsky and suggest he should be more careful to describe the conditions to future participants.

July 13: Cloudy this A.M. Plan to go in helicopter to see Yagilny melange. Briefing in A.M. on this. 1155—helicopter arrives with a new group from Moscow (Czech film team with them). We feel like veterans as we watch them battle bugs. Took photos from helicopter going by "red mountain" (Srednyaya). Landed in a high valley southwest of our camp area. Went west upstream to see red mudstones, tuff. Then back to main creek for lunch. Clouds closing in. Had "sushi," then boiled reindeer and bread. Spent afternoon slogging up headwaters of Volchak River and over snowfields to serpentinite. Saw red rock, siltstone, pillow lavas [typical

seafloor formations] along the way. Rain heavy most of the time; everyone soaked except Akira, who has produced a folding umbrella. Volcanic sequence has steep dips to the east. Helicopter arrived about 1700. Weather very marginal, helicopter had to go long way around following rivers back to camp.

Had sauna (*banya*) after arrival. A new experience for Akira and me [see Box on pages 60 and 61], but felt good after the cold rain. We were guided through the procedure by Victor Chetuzov, our "camp counselor." After sauna, can wash in more conventional way using basins of hot water heated in old oil drum outside. Also can shave, wash clothes.

July 15: Clear and warmer this A.M. Gritchka for breakfast (like couscous). Later learned that it is buckwheat. Then more drying and housekeeping in tent....1157–Helicopter ready, must leave some people behind because air is too warm to support all of us! Landed on the SW side of Ceraya (Gray) Mountain....Went directly up mtn, into cirque and across snow field with Akira to rock buttress (amphibolite) in cirque. Our support group went down into base of cirque to prepare lunch beside stream. They look very small down there. We climbed buttress (lots of loose rock)...traversed just above headwall to northeast, looking for tonalite exposure (wrong end of mountain!). Met Feodor and Evgenii and went east to summit plateau. Very cold and windy up there, clouds and showers closing in from the southeast. Lots of stone rings and solifluction terraces produced by heavy frost action on summit....Long hard descent over frost polygons and loose rock slides on south wall of cirque. Wish I had my own boots on for this trip....Had late lunch and tea (about 1600) and then hiked back up to spot where helicopter recovered us—weather now very marginal for flying.

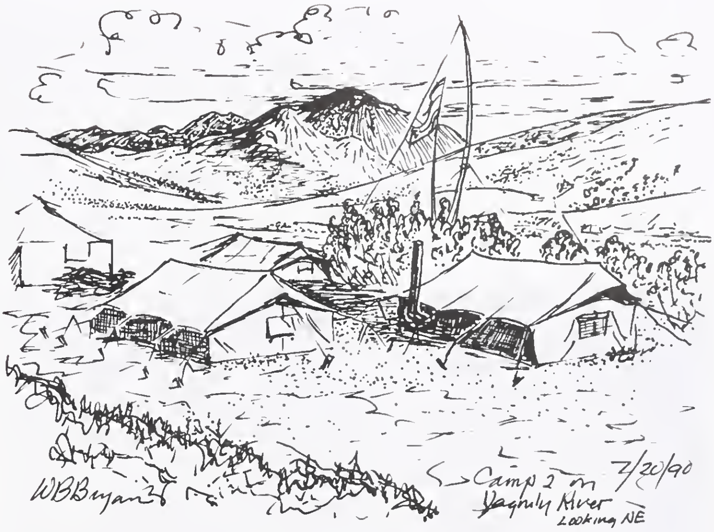


Bryan sketched Ceraya Mountain during a lunch stop. (His first transliteration of "Gray" Mountain was Chirinay—see notation on drawing—while later he thought "Ceraya" more accurate.)

This evening the wind is strong from the south and we spent a lot of time trying to adjust chimney and get a fire going in the tent. Victor put a prop under the chimney to tilt it away from the wind—that helped. At 2200 raining hard. Another crisis when the stove fills the tent with smoke. Finally took some of the wood out—we will be better off if the fire goes out.

July 16: Very windy all night, had little sleep. Very cool, showery this A.M. Our feet are still very sore, so this morning Sergei demonstrates use of felt wrappings on feet, used with boots.
"Is better than socks," he says.
Tony, always suspicious of Russian inventions, is not convinced.

"Perhaps."
"Oh Tony, of course is better!"
"Perhaps."
All of us except the Russians complain about the hot, clumsy boots. My wool socks slide down in the boots and bunch up uncomfortably. The felt wrappings may be better? Perhaps. But the boots are useful in the many river crossings. Use morning to try to wash clothes and self in the river. Some success with the clothes but mosquitoes too vicious to do more. Weather remains windy, showery. At 1245 we learn that it is too bad to go out today.



Bryan's field diary describes this second camp high in the mountains on the upper Yagilny River as "drier, with fewer mosquitoes."

July 17: This is our seventh full day in the camp. Akira says we now have only two times as much to survive! Today began cool and overcast. After breakfast we board the "terrible machines" to go to Srednyaya (Thursday) Mountain.

We make the usual periodic stops to hammer the tread links back together, and one longer stop to fix the transmission. Tony gets out and shows his contempt by walking on ahead—we pick him up again almost a mile along the trail. Some of the track is very rough, and we are banged and jostled about in the back of the vehicle. The final approach is up a narrow stream on the west side of Srednyaya. We climb a ridge to a limestone pinnacle....Collected dunite with spinel bands in stream, and a massive chromite band from the rock glacier. Ascended to high pass on the north side of the mountain.

July 20: Clearing this A.M. Spent morning drying bedding, etc. It has become very sunny and hot....1330—Waiting with all things packed to go to [second] camp. About 1400 helicopter arrives; we get in with Mikail, Tony, Sergei, Vadim, and the Czech geologists. The cooks and their dog, Moukhtar, also come with us. Moukhtar does not like helicopters but is very patient. The new camp is nestled among high mountains on the upper Yagilny River. It is drier, with fewer mosquitoes.

Dinner is boiled potatoes and fried "Spam," dill pickles. We eat this outside, at tables set up in the sun. It is very pleasant—like a family picnic.

July 21: Clear and warm this A.M. Rice for breakfast. Will make circuit around and over south flank of Kamin Mtn. On the way up to the cirque we see pillow lavas...on ridge at crest of cirque views are to south, west, and north. View to south is a "moonscape"....1206 Becoming overcast. Crossed ridge and down to creek for lunch.

Akira has an American map of this area that he bought in Tokyo. We try to locate this place on the map without success. Anatol finds this amusing. "Your intelligence is bad," he tells us. He produces an excellent Soviet topographic map which is clearly much better, and we photograph this for later reference.

Descended east side of ridge and followed stream to northeast. Collected samples of: gabbro, peridotite, altered picrite, and serpentinite. Ended up at sheeted dikes along north side of Yagilny River. Very long hard slog back to camp through tundra along river....Looks like bad day coming. Had dinner outside in light rain. Potato soup (good) and macaroni. Hard rain this evening. Rain all night, heavy at times, keeps us awake.

July 22: Very cool, damp this A.M. (as usual). We huddle in the one large tent for breakfast. Thin potato soup, and a porridge of white sauce and macaroni. The usual tea and bread and butter. A few finish the raw fish.

Expedition Leader Anatol Stavsky, left, lunches with Victor Chetuzov (the "camp counselor"), and Gerda, one of the cooks. "Stavsky," Bryan says, "is more poet than scientist."

Victor comes to help us with the stove again. He shaves off thin strips of dry wood. "How! Indian," he says. The stove is very reluctant to respond even to him. He finally fills it with wood, so the fire has to find something to burn. Soon it is roaring. He finds a string to secure our chimney plate. The tent finally heats up.

Weather still not good after lunch, but we go in the "T.M." to see the olistostrom in the Elgavayam melange to the southeast, on the Mali Ceraya River. On the way we experience a total eclipse, at about 1610. The thin overcast is an ideal filter for observation. It gets gradually darker and cooler, then all of a sudden it gets very dark. There is a cool breeze and a light mist begins to fall. We stop the "machina" to watch and take pictures. It is a very spooky experience in this place.

On the last river crossing the "machina" loses another wheel bearing. Some parts probably swept away in the river....We see limestone blocks, chert, cruddy volcanic rocks. Showers threatening all around....Learned we could eat the pine nuts in the cones on the scrubby trees, but it is a very sticky exercise. Not much luck finding fossils...Akira and I go back alone to the first outcrop, where he has left his large backpack. It is a great place for bears, and we have no rifle. Fortunately no encounters. The vehicle is fixed when we get back, but there is no bearing cover. Sergei and I walk back along the track looking for it, with no luck. The driver wires a piece of canvas over the end of the axle. I think it will not stay there through more than a few river crossings. However this "fix" will last for the rest of the trip!

July 23: Very cool, overcast. Not many at breakfast (left-over gritchka, thin cream soup, and bread)—many seem to have a bad cough. Akira builds a fire to ward off the cold....Our plan today is to go up mountain to the north of camp. Those who are willing get into "T.M."....We see picrite, gabbro, diabase, andesite, and possible dacite. Looks arc-related.

July 24: Clouds low but broken this A.M. Gritchka and milk for breakfast....1025—Waiting to see if the helicopter will come. Now sunny with patches of blue sky here....1500—Weather bad in Anadyr, will not leave today....1900—Dinner is potato soup with some canned meat, bread, and tea....We made a hot fire in the stove and managed to stay awake until 2200. Violent wind gusts come down the valley to the east, wake us up periodically.

July 25: Raining and cold this A.M....Dodonov gives presentation on Bering Sea tectonics. Begins by apologizing for not shaving. (I have relied on Akira's battery-powered shaver—bugs too bad and water too cold to shave with razor.) He tries to explain everything by "synergetics." This is a somewhat philosophical approach espoused by certain Russians—it is a little like "chaos" theory or the things we do with fractals. Mikail does not believe him—finally translates some of this very apologetically.

We have more discussions about plate boundaries. To my surprise, Dodonov says, "Here, we are on North American plate." He smiles. "Until two years ago we were not allowed to say that." He shows me the plate boundary accepted by most Soviet and American geologists who have worked in Alaska and the Soviet far east. It is a rift marked by recently active volcanoes that extends north and west of Chukotka.

Rain continues—we are told the helicopter is coming anyway....Finally we leave, flying low down the river valleys, arriving at the first camp by 1530. It is raining very hard...a lot of new firewood at our tent, but our stove did not make it onto the helicopter. We get into our sleeping bags to get warm. A fine mist continually comes through the tent....1730—Dinner is gritchka and canned meat, mushroom soup....1908—Now back in sleeping bags—still raining hard and misting in the tent.

During a rest stop on the traverse of Ugrumaya Mountain, Bryan photographed part of the field party against a distant mountain landscape.

July 26: Rained hard most of the night—fine spray through tent. Used double sleeping bags to keep warm...in bed almost 12 hours! Back is tired from too much lying down. The mosquitoes returned as soon as rain stopped; had to light coil about 0300.

July 27: Almost no clouds this morning. Cold early but will warm up with sun. Breakfast is macaroni and meat, gritchka, pickled tomatoes, and the usual "*kleb* and *macla*"....Into field at 1000 by "T.M." We are at Ugrumaya (Gloomy) Mtn. Hiked up creek to south, then NE up same creek to snowfields; had lunch there. Sunny and almost no wind. Mosquitoes like this weather, too. Good view of Srednyaya from here. Lunch is bread and

sardines....We have seen tuff, plagiogranite, and dacite dikes, and rhyolite. Does seem to fit island arc concept....

Party this evening. With dinner, had scotch, cognac, and vodka, each with a toast or two or three or more.

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From here, it was possible to review the whole story of the growth of Chukotka over the past 150,000 years.

In spite of the rigors, I came away with many pleasant memories. July is summer in the Korijak Highlands, 300 kilometers south of the Arctic Circle. It is a time of incredibly intense but brief activity, as all living things take advantage of the 20 hours of daylight to prepare for the long winter that has only just retreated and will soon return.

July is the time for salmon to run in the rivers, and our camps were well supplied with fresh fish. The kharios, a dark-gray fish that can grow to five or six pounds, provided much sport for our fishermen. Cut in large pieces and boiled with potatoes and garlic, they provided a savory fish chowder. On other occasions, pieces of boiled fish would be served on a bed of "gritchka," a variety of buckwheat that became one of my favorite boiled grains. Soaked in salt water and then dried for a day or two, these fish made excellent "trail rations," which we ate at noon with our bread and tea.

In July the Chuckchi people drive their reindeer herds into the mountain valleys; it was one of these herds we had seen on our flight in. Our base camp had a plentiful supply of meat from this herd, which was kept just up the valley of the El'Govayam River. Reindeer stew also became another trail lunch; it was carefully transported in a large aluminum kettle and reheated over the same fire that boiled river water for our tea.

All of summer is crowded into the month of July. By the middle of August, I was told, snow flurries would again settle in the valleys as the gales blew in from the Bering Sea to the east. July is the time when every plant bursts into flower; we could not traverse the valleys without trampling thousands of them, and in the high mountain valleys we stepped over and around vast natural rock gardens of miniature rhododendrons and forget-me-nots. The gravel bars in the rivers were covered in the pink flower the Russians called Ivan-Chay; it resembles the fire-weed common along New England roadsides.

My Russian friends were delighted with my interest in their plants. During our daily excursions into the mountains we collected bouquets of flowers to decorate our dinner table. Bunches of wild onions and mushrooms went into the stew; Akira commented that the mushroom soup created by our camp cooks would sell for $100 in Tokyo! Indeed, we probably ate better than people in Moscow; the news brought to us by helicopter from Anadyr told of growing shortages and long lines to buy food and other basics in the cities.

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It was on one of those delightfully sunny late July days that we boarded the helicopter for our last major excursion. We would fly to the upper slopes of Krasnaya, the large red mountain that had dominated the skyline on so many of our trips and is located almost in the center of what the Soviet geologists have called the Mainits terrane. After circling the peak to evaluate wind and landing areas, we were put down on a

broad ridge on the southeast side of the peak.

The Krasnaya massif, like Srednyaya, is composed of peridotite, the dense rock believed to make up the Earth's mantle, and the largely inaccessible deep layer known to most marine geologists only by its reflection of deep seismic waves 4 to 5 kilometers beneath the seafloor. In some titanic collision over 60 million years ago, a huge piece of the Pacific plate must have been torn apart to a depth of 6 kilometers or more, overturned, and thrust up onto what was then the coast of Chukotka, like a gigantic overturned ice floe on the modern Bering Sea beaches.

The field party stops for lunch near snow and amid loose rocks on Ugrumaya Mountain.

From here, it was possible to review the whole story of the growth of Chukotka over the past 150,000 years. Laid out before us, each ridge and mountain massif had its own story to tell. Far to the southeast I could see the rounded peak of Ceraya Mountain, marking the exposed roots of some old island-arc volcano. Farther north and to the east was the familiar red peak of Srednyaya with its limestone ostoliths, betraying its origin as the deep roots of a probable tropical Pacific island. To the northeast, Ugrumaya Mountain, true to its name, brooded under the dark shadow of a passing cloud.

According to Anatol, the Mainits terrane where we stood represented the broken remnants of an ancient island arc that had formed far out in the Pacific some 135 million years ago at about the latitude of San Francisco. Another arc formed even farther south, the Ekonay, had collided with the Mainits terrane about 100 million years ago, then both had been carried north together, finally colliding with Chukotka some 40 million years later.

Along the eastern horizon, the jagged ridges of the Ekonay terrane were silhouetted against the sky. I wondered what other mysteries still remained to be revealed in those far blue mountains. Clearly, they would take another whole summer, or perhaps many more, to explore.

Wilfred B. Bryan began his geological career working for the US Geological Survey in the Rocky Mountains in Colorado and New Mexico, and in the Aleutian Islands, Alaska. Field studies in mineral resources, volcanic geology, and structural geology over the past 30 years have taken him to Australia, New Zealand, Iceland, Italy, Newfoundland, Hawaii, and other island groups in and around the Pacific. During the Apollo program, he studied volcanic landforms and structure on the Moon. He is presently a Senior Scientist at Woods Hole Oceanographic Institution.

On Becoming a Soviet Geologist

Author's Note: ***Every culture seems to have its own rites and rituals one must endure to become truly integrated into the group. In Newfoundland, you must kiss the cod and gulp down Screech; in Italy you must survive enormous trail lunches, complete with gallons of wine. In Australia you learn to eat witchity grubs and crocodile tail. In the Soviet Union, you must master a remarkable variety of skills to be recognized as a seasoned field geologist. Toward the end of our trip, I had one more day to try to do it all right:***

I wash clothes, finishing just before lunch (about 1400). It is getting cloudy but the sun is warm when it is out. I hope things dry in time. After lunch we doze and read in the tent for a while. Suddenly I hear rain, so I bring everything in and start a fire. I get my hands smeared with pine pitch while handling the green wood; much of this is transferred to the clothes as I arrange them on the line. A large gray cloud grows over us and it rains the rest of the afternoon, although we can see sun to the south and to the north of us! Is this an omen?

I go to the banya *[sauna] with Victor about 1900, taking a supply of clean clothes. Now a veteran of this exercise, I am determined to do it right. But Victor quickly demonstrates his expertise. He lies in the river, holding a rope to keep from being swept downstream, then gallops up the bank and back into the steam. I stumble in and get arms and legs smeared with mud on the slippery bank. The water is frigid, so I only manage to splash a little over myself, but it does get rid of the mud. I slip on the way out, and end up crawling up the muddy bank, so I stand in the cold rain and pour water over myself with a dipper from the barrel by the* banya*; this removes the mud again, so I can go back in. I manage two cycles and do succeed in getting the pine pitch off my hands. Victor has finished; he is back in his clothes in an instant and off to dinner.*

The dressing room is leaking badly in the heavy rain. My shoes are right under one stream of water coming through the roof. I use the dipper to retrieve water from the barrel and rinse my feet, trying also to clean the floor in the same flood of water. I shuffle my clothes to keep them out of the drizzle coming through the roof. I manage to get underwear back on with only a moderate amount of contamination by mud and other debris from the floor.

I return to the wash room to shave and wash the clothes I have just removed. I put several dippers of hot water in the basin, wash my face, add lather. Where is the mirror? Of course—it is in my Brunton compass. I manage to wash all the lather off my hands, so I can open the compass; this requires two basins of warm water, however. I finish shaving with no further incidents; then remember I was supposed to come in here and rinse and wash before putting on clean underwear. I remember this because Vadim has replaced Victor and he is now going through this routine; he drenches himself and me. It does not really matter because the brief dash through the rain back to the dressing room has me soaked again anyway. I return to rinse myself, and wash the remaining clothes. By now, the dressing room has turned into a kind of shower stall. I can't dry fast enough to keep ahead of it—finally I realize I will probably get wet again anyway on the way back to my tent, so decide to put everything on and dry out there next to the stove.

When I arrive, the stove is almost out, so I go out for more wood. I have to sort through the pile of mixed green and dry wood for pieces of the right size to fit our "mini" stove. There are very hot coals left so I select several pieces of green wood as previously instructed. They are oozing pitch; I lay them carefully on the coals and close the door. The stove roars. I wait a few seconds, then open the door to check on the fire's progress. A wind gust rocks the tent and the interior fills with dark, tarry smoke. I stumble back out into the rain, and look at my hands; they are covered with a sticky mixture of pine pitch, soot, and rust particles from the stove!

At the dinner tent there is a large caldron of watery fish soup. I have learned to dig deep with the ladle to dredge goodies from the bottom; I capture something and bring it up. It is a large fish head which gazes accusingly at me. I put it back and try again. This time the ladle is full of eyeballs without the heads. A third try brings up a large collection of fins. The fourth try is a large meaty piece from the middle of the fish, and I settle for that. A fifth scoop finds potatoes and more eyeballs. I accept the latter as the price for potatoes.

Back at the tent, I sort my sooty but dry clothes and get ready for bed. I discover that in the confusion at the banya *I have put on my old underwear, and washed the new.*

—Wilfred B. Bryan

Developing a New Soviet Ocean Policy

Raphael V. Vartanov

The fragility of the coastal oceanic ecosystem requires an independent policy for coastal-zone management.

Soviet ocean policy was formed over the entire postwar period, but primarily during the 1970s and 1980s as a result of cooperation and interaction among the chief ministries and agencies related to marine activities. These included the ministries of Defense (Navy and Admiralty), Fishery Industry, Marine, Geology, and Oil and Gas Industry, the State Committees on Science and Technology and on Hydrometeorology, and the USSR Academy of Sciences. In addition, our policy was shaped by the frameworks of each of these state institutions. However, the state's priorities extended the strongest influence on internal and external politics and economics.

It is evident that military aspects occupy a principal priority position in USSR marine policy. Historically, parts of the USSR's ideological approach to internal and, particularly, foreign policy were based on the threat of being hemmed in by enemies of the state, as well as real military antagonism with the West. For these reasons, plus the fact that Soviet military leaders and their party-governmental apparatus structures have constantly occupied the highest positions in the Soviet leadership, military factors had priority in shaping the USSR's marine policy. In circumstances where both division of powers and social control over the state have been absent, the result is a strong military predominance in the country's marine policy and a total disregard for ecological problems. Ecological and environmental questions lying outside the framework of the narrow interests of the main state institutions were obliged to content themselves with the so-called "remaining principle," while at the national level, they were traditionally subsidized last.

The table on the next page illustrates, in my opinion, the hierarchy of priorities for Soviet marine policy in the 1970s and 1980s. The high priority of scientific research is explained by special military applications and the traditional development of many spheres of knowledge formed in the USSR over many decades. For example, a significant role was assigned to the fishing industry at a time of acute food shortage (especially animal protein) and a concomitant aspiration to enter the world markets for fish and fish products.

Environmental Protection: A Low Priority of High Complexity

Environmental protection constantly remained at the bottom of the priority list, despite the fact that it specifically addresses coastal-ocean space utilization, which is part of the so-called "complex programs" and plans for regional development. These complex programs, intended to relieve

Possible Evolution of Soviet Ocean Policy Priorities

	1970–1980	2000*	2000**
Military objectives	1	7	2
Scientific research	2	3	3
Bioresource utilization	3	4	4
Marine shipping and ports	4	6	5
Mineral resource utilization	5	5	1
Recreation and tourism	6	1	7
Environmental protection	7	2	6

**Provided considerable progress in the development of democracy occurs and market relations are introduced*

***In the case of considerable progress in the development of market relations under an authoritative government regime*

Priorities held by decision makers determine the course Soviet ocean policy will tread. The numbers represent the hierarchy of importance of seven significant objectives in the opinion of Author Vartanov.

the agency pressure on the USSR's economic policy, proved unable to accomplish their tasks due to their very size and complexity. They were especially inefficient in solving the problem of rational utilization of the littoral zones. The fragility of the coastal oceanic ecosystem, and its direct dependence on processes of the adjoining strip of land, both require an objective and independent policy for the sphere of coastal-zone (including ocean-space) management. The lack of such a policy reduces the efficiency of economic activity in the littoral zones, seriously threatening their ecological state. The USSR's practice confirms this fact: A critical situation has been brought about by the development of industry and agriculture in littoral regions. A particularly complex ecological situation exists in the littoral-shelf zones of the Black, Azov, Baltic, and Caspian seas. The Aral Sea zone has been declared a zone of ecological disaster, and there is a catastrophic socioeconomic and ecological situation in the regions adjacent to the northern part of the Caspian Sea.

In general, the number of valuable commercial fish species and marine fauna is decreasing. The content of contaminating substances in sea sediments is increasing, with maximum concentrations being noted in near-mouth zones and in bays.

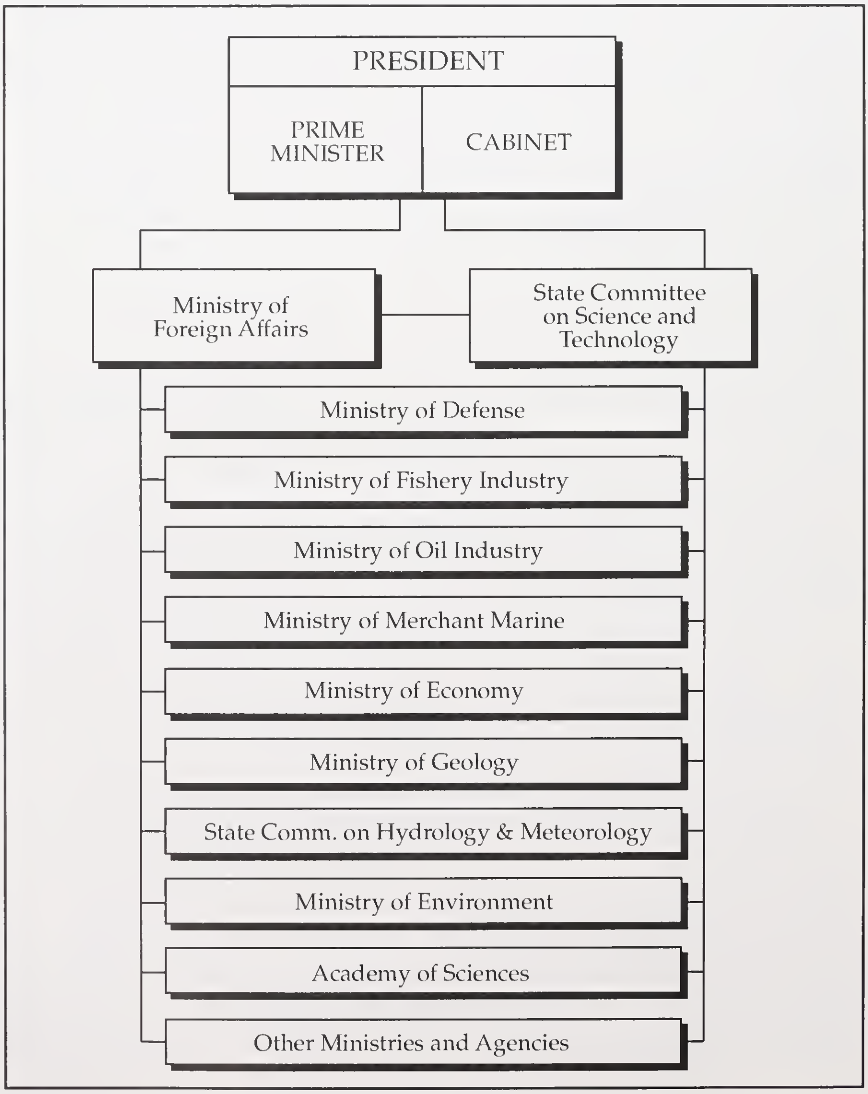
Aggravation of the ecological situations in the shelf and marine zones brought about the vital need for efficient environmental protection measures. Specifically, these were required to reduce the direct disposal of contaminated substances into the marine environment and the volumes of industrial and communal sewage entering river systems, and avoid soluble-substance runoff from agricultural land and other areas.

Not long ago, it seemed that considering these factors and shaping the general state program for oceanic littoral-area use and littoral-zone control was complex, but possible. Now, however, the situation seems radically complicated. Interestingly enough, the USSR's economic situation does not appear to be the source of the complication. Rather, the problems of a jurisdiction demarcation between the USSR and the members of the Federation, and centrifugal trends that have manifested themselves quite clearly recently, hamper not only the formation of a general state policy, but even a forecast of the situation for coming years.

Internal Coordination of a Soviet Marine Policy

Several factors make forming a general state complex program for coastal ocean-space use and management barely probable: The declaration of the intention not to sign the Union Treaty by four out of the six maritime republics (Georgia, Latvia, Lithuania, and Estonia); a radical reappraisal of the concept of sovereignty and sovereign rights for utilization of resources in the two largest republics, the Russian Soviet Federated Socialist Republic (RSFSR) and the Ukraine; and a legislative confrontation involving the RSFSR and a number of republics. In this respect, prospects for forming republican (and in some cases, inter-republican) programs seem most likely. We could, therefore, look to possibly coordinating efforts toward ecological justification at both local and republican levels. Inherent in this approach would be a proliferation of information, data, and new technologies, coupled with a realization of the complexity of the research and development.

Structure of ocean science administration in the USSR



Generally speaking, forecasting the development of this coordination of effort with the formation of Soviet marine policy seems a complicated task, colored not only by vagueness in relations between the central government and the republics, but also by societal changes. The table on page 63 forecasts alterations in Soviet marine policy priorities up to the year 2000, under two sets of conditions. In the first (with considerable progress in the development of democracy and the introduction of market relations), the retreat of military priority within the hierarchy is related not to expectations of a pacifist trend in the democratic societies' development, but rather is conditioned by the fact that this course of events presupposes a more radical improvement in relations with the Western states and an increase in the role of the sovereign independent republics of the Ukraine, Estonia, Lithuania, and Georgia in shaping the national marine policy. One impact of further improvements in relations with the West might be achievement of a nuclear-free zone in the Arctic, and even its total demilitarization. Along those lines, major changes might occur on the Pacific coast of the USSR, connected with our increased involvement with international economic cooperation. Creating free-market enterprise zones is a definite possibility.

In my opinion, as events develop under this scenario, recreation and tourism and environmental protection activity will occupy the top priority positions in marine policy. For this reason, contacts with the USSR would become more attractive to investors and tourists. Developing recreation and international tourism in the USSR's coastal areas is considered, as this could attract considerable amounts of capital, promote development of the infrastructure, and create a positive climate for further inclusion of the country and adjacent regions into the international division of labor.

The processes of formation and implementation of Soviet marine policy reflect the processes taking place in Soviet society.

At present, Soviet marine policy, when considered as an integral part of the Soviet system of executive power, is formed on the basis of the coordinated efforts of two departments: the Ministry of Foreign Affairs (foreign marine policy) and the State Committee on Science and Technology (internal marine policy). These departments also cooperate with one another in making decisions on the directions of marine policy.

Despite considerable progress in solving the power-distribution problem and intensification of parliamentary activity, the USSR's legislative power fails to play an important role in developing complex marine policy. Only separate aspects of marine policy are discussed in the commissions and committees of the Supreme Soviet, and the Supreme Soviet of the RSFSR continues to differ a good deal from that of the Union.

Thus, the processes of formation and implementation of Soviet marine policy reflect the processes taking place in Soviet society. Their dynamics and nature depend on the development of events toward democratization and the interrelation between the central government and the republics and regions of the USSR.

Raphael V. Vartanov is Head of the Section on Ocean Development and Environment at the Institute of World Economy and International Relations of the USSR Academy of Sciences. His current research interests are ocean and environmental management and policy.

Dynamics of Ocean Ecosystems: A National Program in Soviet Biooceanology

Mikhail E. Vinogradov

The main problem facing ocean ecologists is creating a theory of ocean processes that integrates live-matter interactions with nonliving environmental components.

Viewing the environment and its resident populations as a single, interrelated system is one of the most fruitful ideas of contemporary ecology. It has opened vast possibilities for a systems approach to studies of ecological processes in the biosphere. The ocean and its populations are integrated by an abiotic medium, seawater, into a single dynamic ecosystem.

Dynamics of Ocean Ecosystems: A Systems Approach to Biosphere Processes

The two major areas of ocean ecological studies, ocean maintenance and enhancement and protection of marine populations, can only advance with a better understanding of the principles governing ecosystem functioning. Knowing the dynamic laws that govern marine ecosystem development enables oceanographers to predict changes resulting from external forces. The main problem facing ocean ecologists today is creating a theory of ocean processes that integrates live-matter interactions with nonliving environmental components.

Soviet biooceanographers have studied ocean ecosystems for some 20 years. Our work is united under a national program entitled Dynamics of Ocean Ecosystems. It includes studies of abiotic (physical, hydrochemical) and biotic components of the ecosystem as well as their variability and development in time and space. Taking a systems approach, our first emphasis is on the structure and intensity of relations (ecological fluxes) between the system's elements.

Many Soviet research vessels are very large, accommodating 50 to 70 scientists at a time. This allows for full coverage of an ecosystem, and simultaneous studies can include all the main elements of the communities: phytoplankton, bacterial plankton, different groups of protozoa, small and large zooplankton and their taxonomy, sizes, numbers,

An Observation from the Author

Today, as the Earth's population grows rapidly, society pays more and more attention to the ocean as a huge source of biological resources. The ocean occupies 71 percent of the Earth's surface yet yields only 2 percent of total human food quantity. The mass of organic matter synthesized annually in the ocean is greater than that on land, but the economic utilization of the ocean's production is much less effective. Increasing the quantity of marine food products could be possible not so much through increasing the efficiency of modern fisheries as through a broad, scientifically grounded inclusion of organisms from lower trophic levels, and, still more importantly, through wide-scale development of mariculture. I suggest a transition from the exploitation of natural ocean resources to a scientific and rational use of these resources coupled with an increase in intensive farming. This would, of course, require additional effort and economic input.

—M.E.V.

biomass, production, and metabolism, as well as estimates of chemical cycling and energy flux through the system.

Sampling and Subsampling for Population Models

To avoid the negative effects of the usual patchy distribution of organisms in the water column, chemical and biological analyses often examine subsamples of a single water volume. Most samples of the productive surface layer of the ocean are collected with 150-liter bottles, and subsamples are drawn for hydrochemical analyses as well as analyses of suspended matter, chlorophyll, primary production, phytoplankton, bacterial plankton, protozoa, and mesoplankton up to 3 millimeters in length. The water bottles are closed electronically, and they carry devices to measure conductivity, temperature, depth, oxygen, bioluminescence, fluorescence, and water turbidity. Sometimes laser measurements of different sizes of suspended matter are also included.

The ocean occupies 71 percent of the Earth's surface yet yields only 2 percent of total human food quantity.

Larger animals are collected with closing plankton nets and trawls, or are counted visually from manned submersibles. Populations of microorganisms—plankton, bacteria, and protozoa—are assessed with modern fluorescent optical techniques that are applied to living material immediately as it is lifted aboard the ship.

Researchers on ecosystem expeditions examine a variety of oceanic zones including oligotrophic tropical waters, the most productive waters of nearshore upwelling areas, and arctic and antarctic regions. These expeditions offer new data on the development of ecosystems over time, and provide the basis for dynamic mathematical models. Estimates have been made of photosynthetic production in the ocean, bacterial production, and production of different trophic levels of a plankton community. These estimates allow for an evaluation of surface and midwater-depth fish stocks in different ocean regions.

The Precritical Situation in the Black and Baltic Seas

Soviet biooceanographers pay special attention to the most polluted inland waters—the Black and Baltic seas—whose ecosystems are in the precritical state. Regular expeditions to these seas allow us to record changes in their ecosystems. In the Black Sea, for example, over the past two to three years we have recorded a gigantic outbreak of a new settler, the predatory ctenophora *Mnemiopsus leidyi*, imported from the North American Atlantic coasts. In 1989 its mass in the Black Sea was close to 1×10^9 tons, and the effect on local biological communities and fish stocks has been greater than that of all other anthropogenic factors.

Ecosystems studies conducted under the national programs of the Soviet Union form part of large-scale international projects such as the Joint Global Ocean Flux Study. We hope that in the near future contacts between national and international projects will become closer so that all investigations will be more profound.

Acknowledgements: *Our thanks to John Teal of the Woods Hole Oceanographic Institution's Department of Biology for his technical assistance with this article.*

Mikhail E. Vinogradov is a Deputy Director of the P.P. Shirshov Institute of Oceanology in Moscow.

Satellite Oceanography

Vladimir V. Aksenov
Alex B. Karasev

Remote sensing of the ocean from satellites allows quick, repeated global coverage of surface characteristics and collection of information from remote parts of the Earth. This breadth of data cannot be achieved with traditional measurements from ships; in addition, satellites can measure some features, such as surface topography, that simply cannot be measured from ships. While there are drawbacks to satellite sensing—it is limited to surface waters, errors are introduced by the atmosphere and by imperfect sensors that cannot easily be repaired, and complex methods are needed to process the data into a usable format—some remarkable advances in ocean science are due to this remote sensing technique.

Real-aperture radar can "see" at night and through clouds, especially important for northern latitudes.

Among Soviet satellites that have brought important practical and scientific results are the *Ocean-1* class including *Kosmos-1500* (launched in 1983), *Kosmos-1602* (1984), and *Kosmos-1766* (1986). Most recently, an *Ocean-3* class satellite was launched in June of 1991. These satellites are designed for a nearly sun-synchronous orbit with a three-day revisit capability. The major goals of Soviet oceanographers working with these satellites include:

- development of data processing and analysis methods,
- practical application for nothern ocean navigation (of great value to the USSR with its very long northern coastline), and
- tests of advanced types of onboard equipment.

The resolution, swath width, and observed spectral bands for some of the instruments on these satellites are shown in the table overleaf.

Satellite instruments record incoming radiation from the ocean surface in three wavelength ranges: visible, infrared, and microwave. These instruments may be either active or passive, depending on whether they provide their own radiation or utilize natural emissions. At the present time, all three spectral ranges are widely used:

- visible and near-infrared regions (0.4 to 1.1 micrometers) for determining ocean color and estimating bathymetry;
- infrared region (3.4 to 4.0 micrometers and 10 micrometers) for measuring ocean-surface temperature; and
- microwave region (0.8 to 20 centimeters) for providing information on ocean circulation from sea-surface topography and on surface winds, waves, and temperature.

All three spectral ranges are used to determine ice-cover characteristics.

Measurement of wind speed and direction was of particular interest in the development of these sensors. Determinations of wind speeds in coastal zones were found to be less accurate than those of the open ocean, due to the shallow water and limited distance from the coastline. A new approach to processing data from real-aperture radars (also called side-look radars) was developed to accommodate this phenomenon, and has been proven accurate in the Azov and Caspian seas.

Visual and infrared spectral bands of real-aperture radar also allow estimation of ice conditions and show ice-cover features including:
- ice-edge location,
- ice-cover concentration,
- age (thickness) of ice,
- presence of channels and other inhomogeneities in the ice cover, and
- seasonal dynamics of the ice fields.

Real aperture radar can "see" at night and through clouds, which is especially important for northern latitudes. Soviet scientists have learned a great deal about ice conditions from real-aperture radar, and have derived a series of methods for mapping ice fields that are of practical value for piloting ships and forecasting ice conditions. Their accomplishments include mapping the near-edge zone of multiyear ice, identifying one-year ice in winter against a background of multiyear ice, detecting a system of gaps (channels) in an ice cover consisting of multiyear and one-year hummocky ice fields, and describing the dynamics of the formation and movement of large icebergs.

Ships have been guided out of arctic and antarctic ice fields several times using knowledge of these characteristics. For example, the research ship *Mikhail Somov* was led out of heavy multiyear ice near the Soviet antarctic station Russkaya from March to July 1985 with the help of information from *Kosmos-1500*. The satellite's real-aperture radar was switched on over predetermined regions four to six times a day, and the information was transmitted to Moscow. The data were processed with a

Satellites can carry a host of instruments for remote sensing of the Earth's features, and the Soviet Ocean-1 *class has contributed greatly towards those ends. Here are the specifications of some* Ocean-1 *instruments.*

Ocean-1 Satellite Instruments

Instrument	*Radio Frequency (gigahertz)*	*Spectral Range (micrometers)*	*Swath Width (kilometers)*	*Spatial Resolution (kilometers)*
Real-Aperture Radar	9.522		450	1–1.5 2–3.3
Scanning High-Frequency Radiometer	36.7		550	15 x 15
Scanning Multichannel Sensor (Low Resolution)		0.53–0.58 0.62–0.7 0.7–0.8 0.83–1.0	1,950	1.6 x 1.7
Scanning Multichannel Sensor (Moderate Resolution)		0.58–0.68 0.71–0.81	1,400	0.345 x 0.345

complex of other data and transmitted by facsimile to *Mikhail Somov* and an assisting icebreaker, *Vladivostok*. During the four-month period, 305 *Kosmos-1500* images were processed and 84 maps of ice conditions were produced.

Satellites have great potential in oceanography; indeed, they are the basis for a new branch of the science, satellite oceanography. Satellite data is important to such studies as air-sea and land-sea interactions, global circulation, and the global carbon balance. There are significant satellite oceanography components in several international projects including the World Ocean Circulation Experiment, the Joint Global Ocean Flux Study, and the Tropical Ocean and Global Atmosphere Programme. But only the first steps have been taken in studying the ocean from satellites. For future ocean projects, a healthy satellite component will depend not only on a healthy funding scenario, but also on the scientists' capability for developing new methods of processing, interpreting, archiving, standardizing, and exchanging satellite data.

Acknowledgements: *We thank William J. Plant, Senior Scientist at the Woods Hole Oceanographic Institution, and the National Aeronautics and Space Administration for technical assistance with this article.*

Vladimir V. Aksenov, a cosmonaut, is General Director of the Soviet research and production association called Planeta.

Alex B. Karasev is First Deputy General Director of Planeta.

Доброе утро, товарищи!

Good Morning, Comrades!

Part One: The Visiting Scientist's Point of View

Hugh D. Livingston

Two **Professor Vodyanitskiy** *cruises provided a fascinating glimpse into how Soviet marine science is conducted.*

Photos for this article are mostly by Hugh D. Livingston

Each new day aboard R/V *Professor Vodyanitskiy* began with this greeting, in both Russian and English, piped into every cabin on the ship. *Professor Vodyanitskiy*, a biological oceanographic research ship, hails from the Institute of Biology of the Southern Seas (IBSS) in Sevastopol, on the northern shore of the Black Sea. Scientists from the Woods Hole Oceanographic Institution (WHOI), the Massachusetts Institute of Technology (MIT), and the US Environmental Protection Agency (EPA) awoke to this greeting during two *Professor Vodyanitskiy* cruises in 1989 and 1990 as part of a Woods Hole/Sevastopol scientific exchange to study Chernobyl radioisotopes in the Black Sea. These cruises provided a fascinating glimpse into how Soviet marine science is conducted, and an opportunity to develop both scientific and personal contacts with Soviet marine scientists.

The Opening of Sevastopol

Sevastopol is a busy port city situated near the southern tip of the Crimea, right in the middle of the Soviet coast of the northern Black Sea. The city has a long history connected to the sea, due to its natural harbors and strategic location. Remnants of a lengthy period of Greek colonization stand today as monuments to the outreach of Greek naval power. Outside the city stand the partially submerged ruins of the beautiful Greek city of Chersones, built as a key port and trading center on the northern fringes of the Greek empire. The city was founded in the fifth century BC by Greeks from Geracleya, on the Anatolian shore (now the Turkish coast of the Black Sea). One motivation for settling Chersones was to trade with the Scythians, the original people of the Crimea and the South Ukraine. In later years the city was also used for trade by the Genoese. Today, Sevastopol is a major Soviet naval center, important as a

southern warm-water port. It is also an oceanographic research center with a long tradition: Scientists of the Marine Hydrophysical Institute (MHI) and the IBSS study physical and biological oceanography of the Black Sea and the Atlantic and Indian oceans. Founded before the 1917 Revolution, IBSS was the first marine biological institute in Russia and one of the earliest in the Mediterranean region.

Architectural ruins remain as icons to Chersone's Grecian history. The city was originally settled in the fifth century B.C. to enable the Greeks to trade with neighboring peoples.

The onset of *glasnost* and *perestroika* led to the gradual opening of this city. For many years, Sevastopol was off-limits to foreigners and even to Soviets without permission to visit it. Despite the Cold War, French and Italian navy ships called several times, and once a year (at most) Western scientists were invited by IBSS or MHI for day-time-only visits. It was not common for Americans to obtain the necessary permission to enter Sevastopol. In 1989, Woods Hole scientists were among the first Americans allowed to make an extended stay in the city. Also in 1989, the city hosted an historic and emotional port call by the US Navy's guided missile frigate USS *Kauffman* and *Aegis*-class cruiser *Thomas S. Gates*, both from Norfolk, Virginia. In April 1989, arriving in the Crimea for the first cruise of the Woods Hole/Sevastopol scientific exchange, Woods Hole scientists were required to stay in Yalta, about 50 miles east of Sevastopol. We were allowed a half-day visit to Sevastopol, passing through the military checkpoint between the two cities. Instead of allowing the US group to join *Professor Vodyanitskiy* in its home port of Sevastopol, the ship came to Yalta to pick us up and drop us off. For the 1990 cruise, however, we were permitted to stay in Sevastopol, living aboard the ship both before and after the cruise.

R/V Professor Vodyanitskiy *was host ship for the two Woods Hole/Sevastopol Black Sea scientific exchanges described in this article.*

Curiously, Sevastopol has benefitted from isolation from the Soviet Union and the rest of the world. Rebuilt after near-total destruction during World War II, the city retains a pleasant, old-world charm. Many fine buildings are set in naturally beautiful surroundings. As a closed city, Sevastopol has not suffered the tourist development that has brought overcrowding, pollution, and environmental problems to the Crimea and Black Sea tourist centers. As a navy town, it has a maritime atmosphere and the streets are dotted with people in naval uniforms and hats. As recent visitors from Woods Hole, we were struck by the odd appearance of WHOI caps and T-shirts, signs of the developing association of Woods Hole and Sevastopol marine scientists.

Woods Hole/Sevastopol Interactions

Over the years, WHOI scientists from most departments have had connections with their colleagues in Sevastopol, but close associations were subject to the warming and cooling of the political climate between Washington and Moscow. In the 1970s, we attended a symposium on artificial radionuclides in the ocean that was organized in Odessa by Gennady G. Polikarpov, who is head of the Department of Radiation and Biological Chemistry at IBSS and academician of the Ukrainian Academy of Sciences. Polikarpov also visited the WHOI radiochemistry group in this same period.

During the 1989 cruise, many details were worked out to resolve communication problems and pave the way for a more efficient 1990 cruise. Professional relationships flourished, and friendships emerged. Here, Hugh Livingston, center, is flanked by two men based aboard R/V Vodyanitskiy *in 1989.*

There was little contact afterwards for several years, until (in the *glasnost* era) the Chernobyl accident in April 1986 brought the two groups together for joint studies of the assessment and behavior of radioactivity in the Black Sea from Chernobyl fallout (see Chernobyl: Oceanographic Studies in the Black Sea, *Oceanus*, Fall 1987). The explosion of the Number Four reactor at Chernobyl, just north of Kiev in the Ukraine, spread radioactive fallout throughout much of Europe. Fallout deposition was high in the Black Sea, its surrounding region, and many other parts of Europe. More contamination washed down the Dnepr River, from the Pripyat River tributary (on which Chernobyl sits), and into the Black Sea.

Other recent and ongoing WHOI/Sevastopol interactions include the visit to Woods Hole by MHI's R/V *Akademik Vernadsky* in the summer of 1989, and a new initiative by David Aubrey, director of WHOI's Coastal Research Center, to launch a long-term multinational environmental assessment study of the western Black Sea by the Black Sea littoral nations together with WHOI.

The two WHOI/IBSS cruises to study Chernobyl radioisotopes in the Black Sea were in April 1989 and June 1990. Both employed the R/V *Professor Vodyanitskiy* as the principal research vessel of IBSS. We concentrated our study on the northwestern region. This area is important because it may be the formation site of the shallow cold-water layer (Cold Intermediate Layer) found throughout the Black Sea, and it is also the major site of freshwater supply to the Black Sea from rivers such as the Danube and the Dnepr. US participants in the 1989 cruise included Susan Casso and myself from WHOI, and Kelly Falkner from MIT. In 1990, the WHOI group of my wife Stella and I, Mary Hartman, and John Andrews were joined by William Curtis, John Broadway, and James Niehiesel of the EPA. The EPA group was interested in making radioactivity dose-assessment calculations from the contamination of the Black Sea as a result of the Chernobyl accident. Many residents of the Crimea were pleased to hear that US scientists confirmed Soviet assurances that

the contamination of the Black Sea posed no significant health risks to either humans or marine organisms.

These cruises reflected a growing mutual understanding between the visiting US scientists and their Sevastopol hosts. Soviet scientists have long been isolated from the West. This isolation as well as communication problems made advance planning difficult for the first cruise. We expected a cruise in which our work would be integrated into an established, structured cruise plan. In reality, we were offered a leading role; we were asked to organize and plan the cruise around our own objectives. In addition, we were treated as special guests, complete with prime accommodations and laboratory space. Communication and cultural differences hampered a well-integrated joint program. Halfway through the cruise we realized the Sevastopol group was making measurements in parallel with our own at each station—often after the WHOI sampling was completed. We assumed they wanted to compare their results with ours, although we didn't ask them this! During the cruise, many lengthy meetings were required to bridge communication difficulties and to improve mutual understanding.

The Second Cruise

In contrast, the 1990 cruise built on the previous year's experience and went more smoothly. From the beginning, the sampling program was fully integrated and optimized for the differing analytical capabilities of the laboratories. WHOI equipment, sent via R/V *Akademik Vernadsky* after its visit to Woods Hole, was available to supplement the IBSS gear. The results of the 1989 cruise were also helpful in planning an improved science program. Friendships had grown, leading to much easier contacts and interactions.

R/V *Professor Vodyanitskiy*, named after a former director of IBSS, was built in Turku, Finland, in 1976. It is one of a series of research vessels specifically designed and equipped for biological oceanographic study. The ship is 69 meters (228 feet) long, weighs 1,174 tons, and accommodates 32 crew and 28 scientists. Powered by a 2,000-horse-power Deutz diesel engine, it can cruise at up to 14 knots. Deep sampling is conducted from two winches on the forward part of the main deck. A main trawl winch at the stern is used for trawling operations through a hydraulic frame on the fantail. Navigation is via a Magnavox satellite system, a Decca navigator, and both Omega and loran receivers. The ship's 11 laboratories provide ample space for the range of activities associated with biological oceanography. Since the 1990 cruise, it has returned to

Soviet and American cruise participants got together often to enhance mutual understanding. Here, on the 1989 cruise, Scientists Kelly Falkner and Gennady Polikarpov share evening conversation in Captain Tyninika's cabin.

The US science party was amused to find two dogs aboard the ship in 1989, complete with private berths in the form of brightly painted kennels secured to the deck. Zhulka, shown here, gave birth at sea to two puppies that the American group was honored to name Laika and Lassie.

Finland for a mid-life refit and is now back in the Black Sea.

Soviet Seafaring

Life at sea was pretty familiar, as seagoing people throughout the world know well. We only worked during daylight hours, but I'm not sure if this was the usual practice or part of the unusual character of hosting a cruise for Western visitors. The pace of work was more leisurely than on US cruises, where every effort is made to maximize use of expensive ship time. Dining space was generally superior to that of US ships, and a sauna was an unexpected luxury. The crew was most helpful and friendly, and we were able to achieve much of what we wished. Considerable time was spent making the cruise plans, but this was partially to insure that we had communicated properly with each other.

There were some unusual features. On the 1989 cruise two dogs were aboard. This was certainly unconventional, but imagine our surprise when one of them gave birth to two puppies halfway through the cruise! We were invited to name them, and chose Laika and Lassie—the only names we could think of for a dog from each country! Another day each of us was duly presented with six cans of condensed milk, the rations offered to hazardous workers (those whose work exposes them to physical or chemical risk). As chemists we apparently qualified and so we received and signed for the issue. The surprise of the 1990 cruise was the four children aboard. The school year had just finished and they were allowed aboard as a treat, on a space-available basis. The captain, the chief engineer, a scientist, and the cook all had teenaged sons or daughters aboard. This strengthened the existing sense of community, especially since almost everyone came from Sevastopol and knew each other fairly well.

Developing Closer Ties

These cruises are but part of a new era of enhanced interactions between WHOI and Soviet scientists. During a three-week tour in 1990, WHOI director Craig Dorman visited many Soviet oceanographic centers. Two groups of IBSS scientists have visited WHOI as part of a WHOI/Sevastopol Black Sea exchange. Soviet scientists are visiting WHOI with increasing frequency, making extended visits (from two weeks to four months) in different departments, and some WHOI scientists are reciprocating with visits to Soviet laboratories. One student who was aboard the 1990 *Professor Vodyanitskiy* cruise has entered the MIT/WHOI Joint Program in Oceanography and Ocean Engineering. This program of

graduate study in oceanography boasts over 100 students from the US and abroad, studying all aspects of ocean science. A student enrolled in the joint program divides his or her time between MIT and WHOI, and at the end of study a M.S. or Ph.D. is conferred by both institutions. Through the visiting Soviet scientists, cultural exchange is spreading into the Falmouth community that surrounds Woods Hole, with plans under way for a student exchange between two Falmouth schools and a Moscow school.

With help from WHOI, electronic mail links have been established in Sevastopol—adding to the small but growing number of such communication ports in the USSR. A workshop on US/USSR ocean science exchanges is scheduled for October to be held at WHOI. We will examine information about other recent exchanges and bilateral agreements, and try to document objectives that American and Soviet scientists hope to achieve. Such developments portend a future of stronger connections between WHOI and Soviet marine scientists, and reflect the many cultural bridges springing up between the US and the USSR, as the USSR's new social order unfolds.

Part Two: The Social Director's Point of View

Stella J. Livingston

I was greeted by Stanislav Konovalov (call me Stan!), director of IBSS, and told that I would be social director for the two-week cruise.

I had no idea what awaited me as I arrived in Sevastopol on a beautiful summer morning after a 24-hour train journey from Moscow. I was anticipating my first experience on an oceanographic research cruise, and it was to be on a Soviet ship. As a "nonscientist," I assumed that I would be essentially a passenger, willing to help but concerned not to be in the way. I was greeted by Stanislav Konovalov (call me Stan!), director of IBSS, and told that I would be social director for the two-week cruise. The language barrier daunted me—just for a second—but I knew I would enjoy the challenge, whatever that would eventually mean! The cruise turned out to be a thoroughly enjoyable and rewarding experience, and one I would hope to have the opportunity to repeat.

Daily Details, Aye, Aye!

From my first step on board the ship, I was made to feel welcome. I had total freedom in the galley area; knowing my interest in food from my years as a private caterer, I think Stan had arranged this with the huge and wonderful, bearded Peitr "Veliki" (the Great) Keda, who was the ship's head steward. At the time, I could not know that my freedom of access was the source of some curious stares from others in the dining room (little hierarchies did exist).

My only "official" duty was to serve morning coffee to a group of male scientists in the chief scientist's cabin. Although aware of the ste-

reotype in which I was being cast, I knew that in the Soviet Union, roles of men and women differ markedly from those in the US. I swallowed my dislike and played the part.

My day at sea quickly developed into a routine. At 7:00 A.M., the ship's loudspeaker beckoned, "*Dobroy outro, tovarichi.*" I would wake up quickly, throw on clothes, and rush to the bridge to repeat the announcement in English: "Good morning, comrades," followed by the time, date, conditions of weather and sea, and the plans for the day—all to the curious smiles of the crew. After that it was breakfast at 7:30, then coffee at 10:00, often accompanied by Girl Scout cookies, British biscuits, and chocolates that I had brought. (These were much appreciated.) Then, at 11:00 A.M., I taught English to Kolya, the captain's 12-year-old son. We dubbed him Pepsi Kolya to distinguish him from Coca Kolya, also known as Nicolai Stokozov, the assistant chief scientist. By the end of the cruise my class of crew and scientists had expanded to nine. I felt like the Pied Piper as I led my class around the ship going over basic English vocabulary and naming everything in sight. Lunch was at 11:30, followed by the "Admiral's Hour," a break period when little shipboard work took place. I am told that this is not the norm on WHOI cruises! A snack was served at 3:30 P.M. and dinner followed at 7:30. Before each meal, an announcement was made in Russian on the ship's public address system. The chief scientist had me follow that with the English version. At the end of the cruise I was presented with a flag pin for The Best Broadcaster in English.

Many friendships were forged aboard R/V Professor Vodyanitskiy. *Near the end of the 1990 cruise, Author Stella Livingston pauses on deck with Andrey Karachintsev, left, Sveta Makarova, and Sergey Chervyakov, right.*

Socializing at Sea

It was during Admiral's Hour, after about four days at sea, that I developed one of my social-director ideas. I was going to the upper deck to play table tennis with two of the children aboard, 13-year-old Svetlana (Sveta) Makarova, the assistant steward's daughter, with whom I spoke French, and young Kolya. A group of five or six men were there playing table tennis very seriously and working out with homemade (or ship-made) weight-lifting equipment. I was surprised that I had not seen them before. It occurred to me that the other six Americans would not meet all the Soviets on board—other than their scientific colleagues—unless someone created an opportunity for everyone to interact. I hit on the idea of a table-tennis tournament. A Soviet friend, Zosim Finenko, and I posted the notice of the tournament outside the dining room. It drew an enthusiastic response: More than half of the people aboard entered.

I quickly developed a feeling of the timelessness that exists at sea. The days, hours, and minutes soon lost their order. Time felt endless,

even though I had given my day some structure. At the beginning of the cruise I had time to pursue reading, and later I tried helping with some of the chemistry of the seawater samples. I enjoyed that work and took it very seriously. This again caused many stares and smiles as I appeared on the deck in my white lab coat and set about my tasks.

On three occasions I made French bread for the whole ship. I had brought along my own recipe, and the results were thoroughly enjoyed by all. One time the bread served as a perfect complement to a snack of *Spratus spratus*, a common, small, Black Sea school fish brought up in the trawl nets in numbers sufficient to serve both science and the galley.

Another activity was the planning of a women's dinner. The chief scientist kindly agreed to be evicted from his cabin for the evening, and the kitchen produced a wonderful spread for us—and would not allow me even to help. Captain Tymko provided us with champagne and a special cake was prepared. All the women aboard attended, including two Americans and eight Russians. It was a memorable evening, as each group was curious about the other from a woman's point of view.

On two occasions we had swim calls, marking a milestone in my life. Swim calls were greeted with great enthusiasm by all, including me. After I was "helped" down the rope ladder to the water, I swam away from the ship—to the amazement and anxiety (it turned out) of Hugh—because, as he pointed out, I was for the first time in my life out of my depth and at 1,500 meters at that! At my home beach I never swim in water depths over 5 feet. I was amazed at myself. It had never crossed my mind before getting in, and I repeated the exercise a few days later.

Landing the Spratus spratus *was easy: These small fish are quite common and therefore are abundant once the trawl net is raised. Salt curing them, however, first requires getting them into containers—a rather messy and arduous task. Scientist Larisa Migal and Head Steward Peitr "the Great" Keda work in the foreground while a crew member assists them in the background.*

Sharing the Delights of Democracy

The table-tennis tournament continued daily, and required both spectators and umpires—with Russian translations for the scoring. This led to the idea of a prize-giving ceremony, so I started to gather prizes. Since Wimbledon was taking place at the same time, I decided on a money prize for the winner and runner-up, and another prize of some sort for all who entered. These included WHOI pens and pencils, hats and T-shirts, candies, gum, etc. Special prize categories were chosen: the oldest, the youngest, the best-looking girl, the punkiest boy (14-year-old Yuri had a slightly punky haircut), the fittest-looking crew member, the most handsome man, and so on. Little did I know how shocking this was to people unaccustomed to being singled out.

The day of the prize-giving came. It was decided that on this last evening of the cruise, the prize-giving would be followed by a dance party. The Soviet women scientists made a special dish for dinner that evening (*pelmeni*, a Siberian dish of small dumplings that were a mammoth production to create) and dressed up specially for the occasion. The prize-giving, a real novelty, caused much merriment. The handsomest man was greeted with much debate! The women had voted

democratically for the winner. And handsome he was (though not voted so by me). Captain Tymko recited a sonnet with great verve from an earlier interest in acting. Hugh was asked to follow suit, and he recited a poem by the Scottish poet Robert Burns. As the Soviets all knew and liked Burns, this was well received. The evening finished with an impromptu dance that had everyone on the floor. Later I heard the ship had never before been together at such a gathering. The ceremonies and the dance party were viewed as very democratic, as Soviets are accustomed to strong hierarchical modes of behavior. The whole idea was utterly alien to their lives—a fact we did not appreciate at the time.

...And the winner of the prize for the Most Handsome Man is Vadim Kazakof!

We felt a wonderful sense of camaraderie on board, even though we could not speak Russian and thus could not talk easily with most on the ship. It turned out that it was not important. Communication does not always require language, and that was clear on this cruise. My short visit touched me deeply and I returned home determined to learn their language and be able to experience a greater degree of personal interaction. For the last year I have been learning the Russian language. As a guest of the IBSS, I returned this summer to Sevastopol for a three-month visit, hoping to develop a much greater understanding of the Soviets' rich and deep culture.

Hugh D. Livingston is a Senior Research Specialist in the Chemistry Department at the Woods Hole Oceanographic Institution. His primary research interest is radioactivity in the marine environment.

Stella J. Livingston has worked in nutrition and dietetics, and has operated a catering business in Falmouth, Massachusetts. She is currently travelling in the USSR and exploring interests in international relations.

Physical Oceanography: A Review of Recent Soviet Research

Yuri A. Ivanov

The USSR boasts a history rich with scientific endeavor, and ocean sciences are no exception. Since the 18th century, researchers have plied the world's texts with oceanographic discoveries. Our tools today are modern, our technology quite advanced, but our intent is as it was then: to know, always, more. Physical oceanography is the study of water movement, properties, and mixing within the oceans. Some recent physical oceanography studies of eddies, currents, waves, turbulence, acoustics, and climatic change are reviewed here. To look back further in the history of our oceanography, please refer to the article by Leonid M. Brekhovskikh and Victor G. Neiman on page 20.

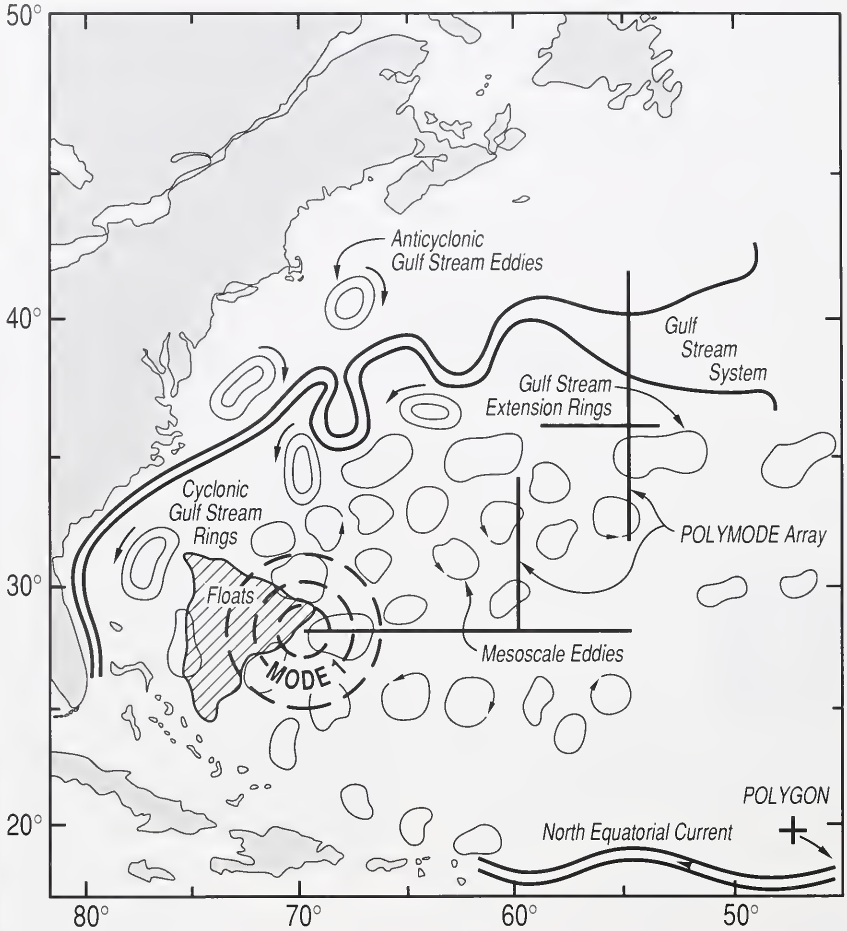
Open-Ocean Eddies

Throughout history, oceanographers' efforts have been hampered by their inability to obtain a time sequence of water movement. The 1960s brought a better understanding of ocean circulation, thanks to newly developed current meters and floats, and, later, profilers such as conductivity, temperature, depth (CTD) sensors. During this time it was discovered that wind over the ocean, coupled with the Earth's rotation, created a strong western-boundary current and the interior of the ocean was thought to be relatively inactive. However, when technological research produced instruments capable of collecting data for time series of 6 to 12 months, the ocean interior proved surprisingly energetic and Soviet oceanographers began to focus on this new finding.

POLYGON-70. In 1970, the P.P. Shirshov Institute of Oceanology, part of the USSR Academy of Sciences, carried out POLYGON-70, a large hydrophysical experiment in the Tropical Atlantic. Continuous measurements of currents and repeated hydrographic surveys were made to study the variability of ocean temperature, salinity, and density fields, as well as the dynamics of open-ocean currents.

Seven research ships took measurements from February till September in the area centered at 16.5°N, 33.5°W. The measurements revealed high-energy cyclonic and anticyclonic perturbations continuously passing through the area. The characteristic horizontal scale, or diameter,

Measurements by seven POLYGON ships revealed high-energy cyclonic and anticyclonic perturbations continuously passing through the area of the experiment.



The North Atlantic was the site of intensive eddy-identifying research in the 1970s. Soviet researchers in POLYGON-70 discovered synoptic eddies there in 1970. The US and UK jointly conducted MODE in 1973, followed by US-USSR cooperation in POLYMODE. This schematic represents areas and significant features that were studied under MODE and POLYMODE.

After Nancy Barnes, based on a map by William Simmons

of the eddies was 200 kilometers, and the vertical scale, or height, was equal to the ocean depth. Later these features were termed "synoptic eddies." They were baroclinic: their orbital velocities, temperature, and salinity varied greatly with depth. Their discovery was a catalyst for other intensive studies of synoptic eddies in various parts of the world ocean, and they later proved to be a characteristic feature of the ocean.

POLYMODE. The US and UK jointly conducted the Mid-Ocean Dynamics Experiment (MODE) in 1973. The combined results of POLYGON and MODE proved the presence of mesoscale eddies that are analogous to the atmospheric high and low pressure systems that determine weather. Their discovery created a fervor in the scientific community, as many wondered if mesoscale eddies would provide the missing theoretical link between small-scale turbulence and general circulation.

From this emerged POLYMODE, a joint effort between the USSR and the US in part to study ocean currents of planetary scale and other questions of ocean dynamics. Preliminary meetings began in 1973, and the experiment was concluded with publication of the *POLYMODE Atlas* in 1986. While MODE studies focused on a 300-kilometer-square area of the North Atlantic, POLYMODE effectively doubled this study area to discover several new types of mesoscale features, including a wavelike

water jet south of the Gulf Stream.

Much progress in mesoscale eddy research was made during POLYMODE, which included the USSR Synoptic-Dynamics Experiment in the Sargasso Sea from 1977 to 1978 and the US Local Dynamics Experiment from 1978 to 1979.

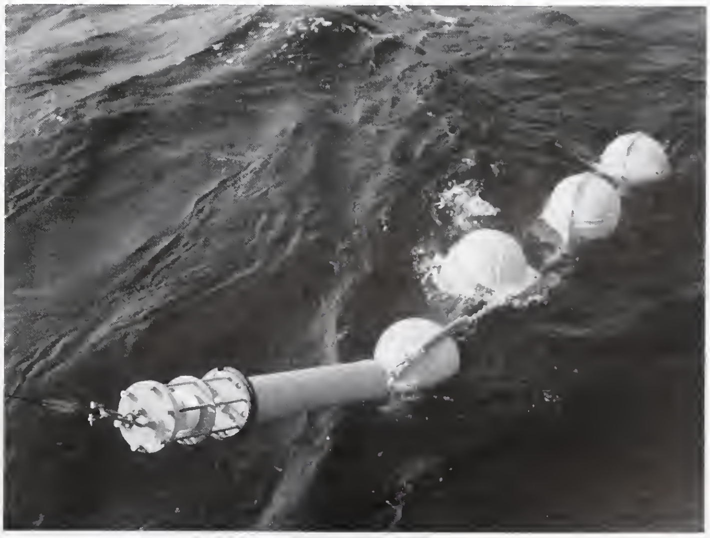
The primary features of open-ocean energetic eddies were determined by analyzing an enormous data set of current velocities, water temperatures, salinities, and chemical properties. In the open ocean, far from the shores, cyclonic and anticyclonic eddies are ubiquitous. Their energy significantly exceeds the energy of mean (long-term average) currents. They tend to move west, they are about 200 kilometers in diameter, and it takes about 100 days for an eddy to move past a point in the ocean.

There are two types of open-ocean synoptical eddies: intensive eddies that can carry water, and larger, less-intensive eddies with wave-like properties. The intensive eddies can be generated by meanders of large-scale currents; eddies with wave properties are generated by atmospheric forcing. Eddy fields are basically nonlinear, making eddies great contributors to heat, salt, and momentum transport in the ocean.

MESOPOLYGON. In 1985, the Shirshov Institute organized "MESOPOLYGON," an expedition of three vessels to study the dynamics, kinematics, and thermohaline (temperature and salinity) structure of mesoscale eddies in the eastern Tropical Atlantic. This experiment showed that synoptic eddies can be regarded as a "background" for the spawning of smaller-scale eddies. The lifetime of the smaller eddies was found to be 6 to 12 days, their diameters ranged from 20 to 40 miles, their mean orbital velocities varied from 20 to 25 centimeters per second, and their vertical scale was 300 meters.

One important result of MESOPOLYGON was the discovery and detailed description of a lense of Mediterranean water that formed a mesoscale anticyclonic eddy. Such an intrusion lense is formed by injecting a water mass into background water, in this case, Mediterranean water into North Atlantic water. The intrusion lense was ellipsoid with a vertical axis. It was located in the 800- to 1,300-meter layer, and its volume was 420 cubic kilometers. In the core of the lense the temperature and salinity differed from that of the surrounding waters by 4°C and 1 psu (practical salinity unit) respectively. These anomalies are the largest known for North Atlantic intrusion lenses. The largest orbital velocities in the lense, 25 to 30 centimeters per second, were observed in the core periphery. Within the lense core, in a 7-mile-radius area, the orbital velocities changed linearly. This means that the core rotated as a

Current-meter moorings played an important role for both Soviet and American POLYMODE programs. The cylindrical device is an American current meter, and the ball-shapes are part of the flotation that holds the mooring wire in a vertical position.



Susan Tarbell


Susan Tarbell

WHOI Senior Scientist Nick Fofonoff has worked for many years with Soviet colleagues. Here he prepares a Nansen-bottle cast to provide readings of temperature and salinity at various depths in the area where a POLYMODE mooring is about to be set.

solid body. Approaching the outer parts of the core, the velocities diminished to approximately zero.

According to the temperature and salinity measurements, the lense transformation occurred by the formation of meanders and small-scale intrusions of the waters trapped in the lense's outer boundary. Comparatively speaking, these processes are slow and provide the large blocks of time necessary for the intrusion lense structures to form.

Eddy-Resolving Models. Technological advances since the 1970s have made mathematical models central to ocean circulation studies. Computer-generated eddy models can reproduce eddy activities over long time periods. They allow scientists to predict real ocean movements and construct hypotheses about global ocean movements and on weather and climate.

A numerical eddy-resolving model has been designed to study open-ocean eddies. A zonal basin open from the West is considered in the model; therefore, it does not deal with western-boundary currents. Analysis with the model reveals that in the quasistationary state, the transfer of an eddy's potential energy to kinetic energy is due to baroclinic instability.

Existing data made it possible to verify the accuracy of the numerical eddy-resolving models, and to study the capabilities of local hydrodynamical forecasts. In 1985, it was found that eddy-resolving models do reproduce the evolution of eddies and eddy dynamics that we observe in the ocean.

Jet Currents and Frontal Eddies

Gulf Stream experiments in the North Atlantic and the Kuroshio are conducted almost annually by the State Oceanographic Institute, the Far Eastern Hydrometeorological Institute, the Shirshov Institute, and the Pacific Oceanological Institute. The Gulf Stream and Kuroshio have a high-velocity core, often called the "jet stream" or "jet current," that is analogous to the jet stream in the atmosphere. This research studies the spatial and temporal variability of jet current systems, primarily by making repeated CTD surveys.

MEGAPOLYGON. From July to October of 1987, the MEGAPOLYGON experiment was carried out in the northwestern Pacific near the subpolar front to study the short-term structure change, intensification,

and weakening of current fields. Eleven research vessels cooperated to set 178 moored buoys with current and temperature meters. Six CTD surveys, with hydrochemical and hydrobiological measurements, were conducted. After the boundary currents depart from the western coast, they divide into branches, forming several jet currents. Their position, number, and water transport amount varies with time. For the Gulf Stream Delta, several types of jet current systems have been identified. Water redistribution within the jets is governed by Gulf Stream water transport and where the bifurcation occurs. The somewhat stationary meanders of the Gulf Stream, Kuroshio, and their respective jets episodically depart from the main current and form frontal eddies or rings.

Ocean Waves, Turbulence, and Fine Structure

Wave studies are conducted in the USSR from both experimental and theoretical perspectives. Early wave theories described waves as linear, and ideas were restricted to the wind-driven aspect of the ocean surface flow. Weak eddies do not transport or advect mass and can be described by linear waves. These form nonlinear or oscillatory waves that are called Rossby waves, after the Swedish researcher who first suggested their occurrence in air. Because any variation of forcing (such as wind, heating, or precipitation) with time will generate Rossby waves, they are an important mechanism in ocean circulation. Nonlinear and Rossby waves differ in their amplitude. Nonlinear effects increase as the amplitude or velocity increases. The existence of long-lived rings and eddies has stimulated much interest and research on solitons, which are single waves or eddies, as opposed to a sequence or train of waves or eddies.

Internal-wave research has been directed toward analyzing linear and nonlinear wave behavior in mediums with varying stratification and current parameters, and studying the effect of the internal-wave generation processes on shear currents. The instability of low-frequency waves (e.g., internal tides) has been studied, as has the global variability of internal tidal energy in the world ocean and the processes of wave generation and dissipation over subsurface ridges and shelf areas.

Turbulence studies have been carried out in various parts of the ocean. In general, experiments have attempted to evaluate the general laws of small-scale turbulence, and prove that it has a discrete local character. This means that spatial and temporal variability exists in areas with turbulent and nonturbulent patches of water.

Susan Tarbell

POLYMODE ships were used as ships-of-opportunity to launch free-drifting, satellite-tracked buoys like this spar buoy for studies of Gulf Stream rings.

Ocean Acoustics

Properties of water masses (and their peculiarities) can be easily studied using acoustics. Characteristics of sound signals such as their spatial and temporal variability, their interactions with each other in water, and the way they are reflected or scattered when they contact other objects all combine to reveal information about the ocean and its bottom.

The study of the acoustical characteristics of sound-scattering layers began in the USSR in 1958 in the Pacific Ocean and the Sea of Japan. Later, frequency characteristics of sound-scattering layers and their vertical profiles were examined. The measurements were analyzed and the concept of sound scattering by the seafloor was developed.

The Soviet "Sections" program is a large-scale ocean-atmosphere study designed to develop a model for short-term climate forecasting.

Many theoretical works were dedicated to studying ray and wave models of noise propagation from surface sources in a vertically stratified ocean. In several models, inconsistencies like sound-scattering layers and internal waves were taken into account, and recently mesoscale perturbations including lenses, eddies, and fronts were added. The theoretical research is primarily done at the Institute of Oceanology, the Acoustics Institute, and the Institute of Applied Physics of the USSR Academy of Sciences.

The Ocean and Short-Term Climatic Change

The *Rasrezy* ("Sections") program is a large-scale study of the interaction between the oceans and the atmosphere. Its objective is to develop a model for short-term climate forecasting. The program is based on observing energetically active ocean zones where large-scale ocean/atmosphere interactions occur. Experimental monitoring is conducted in five energetically active zones: the Norwegian Sea, the Newfoundland area, the Gulf Stream, the Tropical Atlantic, and the Kuroshio. Soviet scientists hope to develop a model of the ocean climate reflecting the main features of large-scale structure and ocean circulation, nonstationary three-dimensional models of the active ocean layer, and nonstationary eddy-resolving models. In the past this program has been operated solely by the Soviets; however, portions of it are now incorporated into the World Ocean Circulation Experiment.

As a new century approaches, the USSR continues to expand and intensify its ocean science explorations, maintaining its heading to know, always, more. Like the interactions of the winds, currents, and eddies, our efforts are increasingly linked with and energized through our partnerships in science around the world.

Acknowledgements: *We are grateful to Nick Fofonoff and Phil Richardson of the Woods Hole Oceanographic Institution's Physical Oceanography Department for their technical assistance with this article.*

Yuri A. Ivanov is a Professor and Head of the Large-Scale Ocean-Atmosphere Department of the Institute of Oceanology at the USSR Academy of Sciences.

A History of USSR-US Cooperation in Ocean Research

Ned A. Ostenso, Alexander P. Metalnikov, and Boris I. Imerekov

In April 1972, various agencies in the USSR and the US were notified of preparations for a 1973 summit meeting between General Secretary Brezhnev and President Nixon. Candidate topics to be considered included a series of bilateral agreements in science and technology, including oceanography. The underpinning philosophy was that individuals in our two countries should start working together on topics of common research interest as a basis for developing broader international accords. An exchange of notes between our two countries established that the Soviet State Committee for Science and Technology and the US National Oceanic and Atmospheric Administration (NOAA) would serve as the executive agencies for administering an oceanographic agreement. It also established the basis for a negotiating meeting held May 21 to 25, 1972, in Moscow.

American representatives from NOAA, the Department of State, the National Science Foundation, the Office of Naval Research, and the Academy of Sciences met with their Soviet counterparts to develop a framework agreement on "Cooperation in Studies of the World Ocean." It was subsequently signed on June 19, 1973, by Foreign Minister Andrei Gromyko and Secretary of State William P. Rogers during a visit of General Secretary Brezhnev to Washington, DC. In addition to specifying protocols for cooperative activities, the bilateral agreement established the principle of open and free exchange of data for the benefit of all mankind. The agreement was to be in force for five years, and was later extended. In general, the effectiveness of our research cooperation has reflected the state of relations between our two nations.

The reporting session also agreed upon six research areas to be initiated under the agreement once it was signed. These included:

A Soviet crew member aboard Academik Mstislav Keldysh, *mother ship of the* Mir *submersibles, (see Diving the Mirs, page 8) sports a hardhat honoring the recent Soviet-American cooperative efforts in oceanography.*

Emory Kristof © National Geographic Society

- large-scale ocean-atmosphere interactions,
- ocean currents of planetary scale,
- geochemistry and marine chemistry of the ocean,
- geological and geophysical investigations, including deep-sea drilling,
- biological productivity of the ocean and biochemistry of individual organisms and communities, and
- intercalibration and standardization of instruments and methods.

Between the May 1972 negotiating session and the June 1973 signing, the climate of cooperation was enhanced in many ways. Secretaries Rogers and Kirillin signed a general agreement on scientific and technological cooperation, and there were multilateral interactions in the Global Atmospheric Research Programme's Atlantic Tropical Experiment (GARP/GATE), fisheries research and stock assessment, the International Whaling Commission, the World Data Centers, the Intergovernmental Oceanographic Commission, the International Indian Ocean Expedition, and others.

The Joint Committee's primary task was to create new opportunities for Soviet and American scientists to work together on basic and applied research problems.

During September and October 1972, a small delegation of American oceanographers visited Soviet research institutions in Moscow, Leningrad, Baku, and Gelendzhik, where they further developed possible joint activities in a number of areas. In October 1972, representatives of the USSR Academy of Sciences and the US National Science Foundation met to arrange USSR participation in the Deep Sea Drilling Program (DSDP—see Box on page 91). Finally, in December 1972, Leonid Brekhovskikh (coauthor of The History of Soviet Oceanology, page 20) led an eight-person team to the US to further refine the potential list of research topics to be pursued under the ocean agreement.

Signing of the World Ocean Agreement, or WOA as it was conventionally referred to, led the way to the first meeting of its governing board, the Joint Committee, in Washington, DC, February 25 to 27, 1974. The Committee's primary task was to create new opportunities for Soviet and American scientists to work together on important basic and applied research problems. The committee approved projects within the six areas identified in the agreement, established working groups, and specified a leading organization for each project. The projects initiated in 1974 were:
- oceanographic observations in support of GARP/GATE,
- air-sea coupling processes in the North Pacific,
- POLYMODE,
- Southern Ocean studies,
- numerical modeling of ocean circulation,
- geochemical ocean sections studies,
- deep-sea drilling,
- transatlantic geophysical survey (TAGS),
- northwest Pacific plate dynamics,
- marine ecological systems and biological productivity, and
- oceanographic instruments and methods.

A number of exchanges and joint cruises followed. However, the North Pacific air-sea exchange and geochemical sections were soon dropped from further consideration under this bilateral agreement because of the growing multinational participation in these studies.

At the Second Joint Committee meeting in Moscow from May 27 to 30, 1975, a total of 15 new and continuing projects were agreed upon.

The new activities included three in ocean-atmosphere interaction; six in marine geology, geophysics, and geochemistry, including deep-sea drilling; three in biological productivity; and one in instrumentation. The committee also agreed to a study of the Indian Ocean's response to monsoons, a study of ocean sedimentation processes, and research on the origin and evolution of oceanic lithospheric plates.

Between the Second and Third Joint Committee meetings, salient bilateral activities included planning for the Northern Pacific Experiment (NORPAX) and the joint large-scale, mid-ocean dynamics experiment called POLYMODE. The TAGS field program concluded with planning for the publication of an atlas of the central North Atlantic Ocean basin and continental margins. In addition to a number of workshops and joint cruises, a major symposium was held in Moscow on marine benthic fouling communities.

The Third Joint Committee meeting in Washington, DC in April 1977 was followed by a Working Group on Geology, Geophysics, and Geochemistry in Moscow in June 1977 to plan a possible major marine geophysical investigation of the northwest Pacific Ocean.

The scheduled renewal of the WOA on June 18, 1978, was complicated by ongoing Law of the Sea negotiations (see The USSR and the International Law of the Sea, page 35). Through the exchange of diplomatic notes, the agreement was extended to December 15, 1978, then again to December 15, 1981.

Meanwhile, joint work in the Antarctic Ocean and the DSDP continued, GATE and fieldwork for the First GARP global experiment was completed, there were joint workshops and symposia on biological productivity, and there was modest progress on intercalibration and standardization. Oceanographers from both nations, after much preparation, launched POLYMODE, one of the most ambitious studies of ocean dynamics ever undertaken (see Physical Oceanography: A Review of Recent Soviet Research, page 81). This program spawned several monographs and the *POLYMODE Atlas*, a Soviet-American bilingual reference text describing interesting highlights of the long-term study.

In Moscow, Oceanus *Authors Boris Imerekov, left, and Leonid Brekhovskikh, center, exchange signed copies of the report of the Joint Committee meeting with John Knauss, US Under Secretary of Commerce for Oceans and Atmosphere and Administrator of the National Oceanic and Atmospheric Administration, in September 1990.*

At the Fourth Joint Committee meeting in Moscow from February 20 to 21, 1979, ongoing activities were reviewed, emphasis was placed on completing these activities, and no new programs were added. The next Joint Committee meeting, scheduled for the spring of 1980, was postponed indefinitely because of worsening international conditions. However, work on analyzing the POLYMODE data continued, with symposia in both countries and personnel exchanges, as did fieldwork in the Antarctic Ocean through a joint Weddell Sea Polynia Expedition (WEPOLEX).

Most importantly, cooperation has brought together the oceanographers of our two nations in lasting friendship.

On December 15, 1981, the World Ocean Agreement was extended for three more years (again through exchange of diplomatic notes), and the Soviets' participation in DSDP ceased at the end of that year. The following year several meetings dealt with data from WEPOLEX and POLYMODE, and there were workshops in biological productivity and biochemistry. Beyond this, scientific activity under the agreement became dormant until 1988.

In March 1985, the US government sent a diplomatic note to the Soviet government proposing extension of the WOA for three more years, effective beginning December 15, 1984. On July 30, 1985, the Soviet government agreed to the extension without change. At a foreign ministers' meeting on September 17, 1987, it was agreed that representatives of the two governments would examine prospects for cooperation with a view to reinvigorating activities of mutual interest. On December 9, 1987, the two sides agreed to a one-year extension of the World Ocean Agreement so they would have time to better gauge the prospect for its future.

A series of discussions between the executive secretaries led to the Fifth Joint Committee meeting in Washington, DC, from October 3 to 5, 1988. Three projects were approved for cooperative studies: Mid-Atlantic Ridge crest processes, geochemistry of North Pacific sediments, and arctic erosional processes with special attention to gas hydrates.

On June 1, 1990, Secretary of State James Baker and Foreign Minister Edward Schevardnadze signed a new Ocean Studies Agreement during a presidential summit in Washington. This new agreement was actually a series of "marine" agreements that finalized boundary decisions in the northern Pacific and Arctic oceans, clarified maritime transport relations, and included a clause securing intellectual property rights.

The First Joint Committee meeting under the new Ocean Studies Agreement was held in Moscow from September 14 to 17, 1990. In addition to continuing ongoing research projects, two new ones were approved: diving physiology and circulation of the Bering and Chukchi seas. Only one research area has endured since 1974: that of southern ocean dynamics. As part of this study, a joint drifting ice station will be organized in 1992 in the Weddell Sea to support World Ocean Circulation Experiment research. After the formal sessions, the US delegation visited several Soviet research institutions in Moscow, Leningrad, and Sevastopol.

Other projects affected by this agreement include the geochemistry of bottom sediments, which emphasizes identifying formation regularities towards forecasting natural resource locations; Mid-Atlantic Ridge crest processes, that combines the USSR's *Tethys* and the US's RIDGE programs; circulation of the Bering and Chukchi seas, an effort towards

encouraging further Soviet-American cooperation in fishery and marine ecological research; arctic erosional processes, which explores that vulnerable area; and gas hydrates, an effort to unveil the vast natural gas deposits known to exist in the world ocean. Most recently, the Soviet delegation presented two new topics for consideration: near-bottom oceanology and orientation and communication of marine mammals.

The cooperation outlined above has led to scores of published papers and several books. It facilitated pioneering research ranging from the study of ocean mesoscale dynamics to parasitology and pathology of marine organisms. Most importantly, it brought together the oceanographers of our two nations, forming bonds of lasting friendship. With increasing public concern over threatened changes in the global environment and a heightened interest in the international community in working together to better understand the controlling processes, the USSR and the US are once again positioned to show bilateral leadership in the ocean sciences.

The USSR and the US are once again positioned to show bilateral leadership in the ocean sciences.

Acknowledgements: *We thank Tom Murray of the National Oceanic and Atmospheric Administration's Office of Oceanic and Atmospheric Research for technical assistance with this article.*

Ned A. Ostenso is Assistant Administrator for Oceanic and Atmospheric Research for the National Oceanic and Atmospheric Administration. He has been involved with USSR-US cooperation in ocean research since its formal beginning in 1972, when he represented the Office of Naval Research at the first negotiations meeting in Moscow.

Alexander P. Metalnikov is Deputy Chairman of the State Committee on Hydrology and Meteorology.

Boris I. Imerekov is Head of the Oceanography Department at the USSR State Committee for Science and Technology.

USSR Joins Ocean Drilling Program

In May of 1991, the Soviet Union became the 20th member-nation of the Ocean Drilling Program (ODP), a long-term international scientific venture to explore the Earth's ocean basins. ODP also includes 15 European countries from Scandinavia to Turkey and Greece, as well as the US, Canada, Australia, and Japan. Negotiations between Washington, DC, and Moscow had been under way almost since the inception of the ODP program in 1983. After several false starts, the US in January formally requested that the Soviets join the international research effort. The Soviets also participated in ODP's predecessor, the Deep Sea Drilling Project, from 1974 through 1980. ODP members share technology, resources, ideas, and expertise toward a better understanding of the Earth. The program's drillship, *JOIDES Resolution*, is currently working near the Juan de Fuca Ridge in the eastern Pacific, off the state of Washington.

Polar Oceanography

Part A: Physical Science, 406 pp. - $69.50
Part B: Chemistry, Biology, and Geology, 353 pp. - $65.00. Edited by Walker O. Smith, Jr. 1990. Academic Press, San Diego, CA.

These volumes represent an excellent technical synthesis of the polar oceanography field. Although polar oceanographic research is expanding rapidly, the 20 contributors (from Canada, France, Germany, Norway, and the US) kept the volumes up to date by including references published through 1989.

The first volume emphasizes the physical sciences—polar meteorology, sea ice, remote sensing, physical oceanography (large-scale, mesoscale, and small-scale processes)—and the application of models to polar oceanography. In many respects, *Part A* could admirably serve as a graduate-course text in polar oceanography.

The second volume, *Part B*, reviews chemical oceanography, biological oceanography (phytoplankton, zooplankton, upper trophic levels, and benthos), and particle fluxes. Taken together, the 13 reviews represent a state-of-the-art treatise that will become a highly valuable and welcome reference for practicing oceanographers, students, and scientists from other disciplines. Considering that *Polar Oceanography* is one of the first broad treatments of modern high-latitude oceanography, both volumes are important acquisitions for all marine-science libraries.

Walker Smith, a polar-biological oceanographer at the University of Tennessee, has done a laudible job as editor in the difficult task of pulling together diverse topics. The layout of chapters and clarity of figures are particularly impressive. In fact, the publisher, editor, and contributors have obviously taken extra care with the myriad of detailed maps, vertical profiles, schematic drawings, and model output data.

The short tables of contents at the beginning of each chapter are also very useful. They made the volumes all the more a "ready reference." All chapters are well-researched and cite significant Western polar literature. The lists of references (at the end of each chapter), taken as a whole, are perhaps one of the most important contributions of *Polar Oceanography*. My only complaint is that nearly all of the chapters list only a handful of Soviet pa-pers, if any. The sole exception is chapter 10 (polar zooplankton), by Smith and Schnack-Schiel, which includes more than 30 Soviet articles and books. Hopefully, as change comes to the USSR, Western oceanographers will gain more access to the sizable body of Soviet scientific literature available on the Arctic Ocean.

Polar Oceanography should appeal to a broad range of readers. Two chapters, on meteorology and small-scale processes, are more theoretically oriented since they emphasize aspects of boundary-layer theory. The sea- ice chapter provides a balanced review of the distribution and characteristics of sea ice found in the Arctic and Southern oceans. The chapter on large-scale physical oceanography by Carmack is highly readable and provides concise bipolar coverage; his illustrations are particularly revealing about the subsurface flow of both polar oceans.

The chapters on chemical and biological oceanography provide thorough comparisions between the two substantially different oceanic environments. The final chapter (13) contains a useful comparison of pelagic fluxes in the northwest Nordic Seas and the Atlantic Southern Ocean, and a thorough discussion of the differences in physical and biogeochemical settings of the two regions. I found the chapters on remote sensing and modeling to be valuable and easily understandable overviews of potentially complex and specialized subjects.

While the chapters are not tightly woven together, I sense some synergism, particularly when they emphasize the fundamental problems to be solved and the dearth of measurements in the high latitudes that make resolution of those problems difficult at best. In the preface, the editor makes two highly relevant points—that "polar oceanography is perhaps

even more interactive than temperate and tropical oceanography," and that the "polar oceans have a profound effect on many large-scale oceanographic processes." Both volumes of *Polar Oceanography* provide key insights into these thoughts through their thorough summaries of the current scientific literature and the posing of significant research questions for the field.

Lawson W. Brigham,
Captain, US Coast Guard, and
Guest Investigator, Marine Policy Center,
Woods Hole Oceanographic Institution

Water: Gift of Life

by VHS Video Production, 1990. The Nature Company, Berkeley, CA. 48 minutes - $39.95.

Water: Gift of Life is The Nature Company's premier installment in its Nature Video Library series. For those not familiar with it, The Nature Company is a California-based retail and catalog company that emphasizes nature in its merchandising.

The video is about water in all its forms and elements, where it comes from, and how it evolves through nature. The quality of the images is impressive. One segment soars through beautiful cloud formations against an azure sky; in another, water droplets fall to Earth in slow motion. The photography is stunning with crisp, true-to-life pictures.

Overall, the original score composed for this video is appropriate, but at times the music gets in the way. How many of us haven't been mesmerized by the mere sound of water? This production needed more natural sound. For example, in one sequence, a bear runs full stride through water in pursuit of his next meal. I wanted to see and hear the bear splashing about. Instead, the music masked what could have been a symphony of sound.

Gregory Peck narrates in a lyrical manner that fits the overall inspiration genre of the video. However, the script does not match the superb images. It had little continuity and little information, except for nuggets of facts here and there. As was the case for natural sound, I found myself wanting more.

At 50 minutes, this video is a bit too long without causing one to become fidgety, if not downright bored. To get the most from *Water: Gift of Life*, one should be at one's tranquil best. It is a reflective production that tries to entice and capture water's power, serenity, and raw beauty for the viewer. Aside from the excellent photography, it didn't work for me; but bear in mind, I am not a big fan of inspirational video. If you need more than pretty pictures to attract your attention, this isn't for you. However, if you are in the mood for a "video experience," then pop in the tape, and experience.

Sonya Hagopian
Media Coordinator,
Public Information Office,
Woods Hole Oceanographic Institution

Kingdom of the Third Day

By Indiana University, 1990.
Audio-Visual Center, Bloomington, Indiana.
30 minutes - purchase $160.00/rent $30.00

Kingdom of the Third Day is distributed by Indiana University's Audio-Visual Center, and is part of a larger videotape series entitled *The Battle for the Planet*. The title is a reference to creation of the Earth and the seas in the Book of Genesis. This videotape ambitiously undertakes to deal with the topic of marine pollution in a half-hour time frame. Its major narrator, Viktor Sebek, is identified as an international lawyer and as an advisor to the Advisory Commission on Pollution of the Seas (ACOPS).

In a short period of time examples are given on a broad range of marine pollution issues and current efforts to address them. Particular reference is made to the coast of Wales and pollution problems of this area including sewage outfall, industrial waste, and nuclear-

waste-material dumping. The video presents a disturbing picture of sewage and industrial contamination of the Welsh coast. Questions are raised about public health, and governmental attempts to cope with problems are briefly examined. Sewage and industrial pollution are dealt with in the initial portion of the video, then focus shifts and broadens to address ocean dumping of nuclear waste. Sewage, oil, heavy metals, and other legacies of the industrial revolution are pictured as lesser concerns when compared to the threat of nuclear contamination.

Footage of Greenpeace activity and of a US scientist who is an opponent of nuclear power is balanced to a degree by references to supporters of the nuclear industry and by a segment of an interview with the chairman of ACOPS, who favors nuclear-waste disposal at sea. The recent history of international efforts to control ocean dumping is recounted, and the weaknesses of the international system in dealing with this problem are briefly examined. The narrator's conclusion is that the risks of nuclear contamination are so great that they require ocean disposal of nuclear waste to be considered "guilty until proven innocent."

This video is useful, as it offers those unfamiliar with these issues a means of exposure to the rudiments of the marine-pollution debate. It was obviously produced by those favoring a different philosophical and conceptual approach to ocean dumping than that traditionally observed. The narrator argues that new technologies have been traditionally given the benefit of the doubt until proven dangerous; it also argues that we all too often govern by reacting to crisis or catastrophe rather than by long-term planning. Although *Kingdom of the Third Day* is a useful educational tool to those unfamiliar with the subject, it would benefit from a format longer than one-half hour. Some viewers may wish *Kingdom of the Third Day* offered a greater degree of depth and balance.

N. Bartlett Theberge
Professor and Chairman,
Department of Ocean & Coastal Law,
School of Marine Science,
Virginia Institute of Marine Science
The College of William and Mary

BOOKS & VIDEOS RECEIVED

BIOLOGY

Ecology of Estuaries: Vol. II - Biological Aspects by Michael J. Kennish; 1990 (revised); CRC Press, Inc., Boca Raton, FL; 391 pp. - $195.00.

Fossil and Recent Sponges by J. Reitner and H. Keupp; 1991; Springer-Verlag New York, Inc., New York, NY; 608 pp. - $180.00.

The Preservation and Valuation of Biological Resources edited by Gordon H. Orians, Gardner M. Brown, Jr., William E. Kunin, and Joseph E. Swierzbinski; 1991; Univ. of Washington Press, Seattle, WA; 314 pp. - $40.00.

RECREATION

The Book of Waves: Form and Beauty on the Oceans by Drew Kampion; 1989; Arpel Graphics, Inc., Santa Barbara, CA; 200 pp. - $39.95.

Lagoons produced by Films for the Humanities & Sciences, Princeton, NJ; color, 28 min. - purchase $149.00/ rental $75.00.

Shipwreck Diving: A Complete Diver's Handbook by Daniel Berg; 1991; Aqua Explorers Inc., East Rockaway, NY; 87 pp. - $12.95.

Waves and Beaches produced by Films for the Humanities & Sciences, Princeton, NJ; color, 20 min. - purchase $139.00/ rental $75.00.

OCEANOGRAPHY

Fundamentals of Ocean Acoustics edited by L.M. Brekhovskikh, L.B. Felsen, and H.A. Haus; Springer-Verlag New York, Inc., New York, NY; 280 pp. - $45.00.

Geology of the Continental Margin of Eastern Canada (offshore zone from Georges Bank to Nares Strait) compiled and published by Canada Communication Group; 1991; Quebec, Canada; 914 pp. - $70.00.

Global Climate and Ecosystem Change edited by Gordon J. MacDonald and Luigi Sertorio; 1990; Plenum Publishing Corp., New York, NY; 241 pp. - $69.50.

Ocean Variability & Acoustic Propagation: Proceedings of the Workshop held in La Spezia, Italy, June 4-8, 1990 edited by John Potter and Alex Warn-Varnas; 1991; Kluwer Academic Publishers Group, Boston, MA; 620 pp. - $99.00.

Sea Levels, Land Levels, and Tide Gauges by K.O. Emery and D.G. Aubrey; 1991; Springer-Verlag New York, Inc., New York, NY; 432 pp. - $59.00.

Volcanoes of the Antarctic Plate and Southern Oceans (a selection of the Antarctic Research Series) edited by Wesley E. LeMasurier and Janet W. Thomson; 1990; American Geophysical Union, Washington, DC; 487 pp .- $55.

ENVIRONMENT

Marine Pollution and Sea Life edited by Mario Ruivo; 1990; Fishing News Books, Osney Mead, Oxford, England; 654 pp. - £26.50.

SPILL! The Story of the *Exxon Valdez* by Terry Carr; 1991; Franklin Watts Publishing, New York, NY; 64 pp. - $18.90.

Wetlands: A Threatened Landscape by Michael Williams and Edward Blackwell; 1991; Institute of British Geographers Special Publications Series, London, England; 419 pp. - $79.95.

FISHERIES

Aquaculture: Principals and Practices by T.V.R. Pillay; 1990; Fishing News Books, Osney Mead, Oxford, England; 575 pp. - $59.00.

Crabs of the China Seas by A. Dai and S. Yang; 1991; Springer-Verlag New York, Inc., New York, NY; 600 pp. - $195.00.

The Effects of Fishing edited by W. Craik, J.P. Glaister, and I.R. Poiner; 1990; ISBS Inc., Portland, OR; 206 pp. - $30.00.

Seafood Safety: Committee on Evaluation of the Safety of Fishery Products edited by Farid E. Ahmed, Institute of Medicine; 1991; National Academy Press, Washington, DC; 432 pp. - $49.95.

BOOKS & VIDEOS RECEIVED

MARINE POLICY

Saving the Mediterranean: the Politics of International Environmental Cooperation by Peter M. Haas; 1990; Columbia Univ. Press, New York, NY; 303 pp. - $42.00.

Study of the Sea: the Development of Marine Research under the Auspices of the International Council for the Exploration of the Sea compiled and edited by E.M. Thomasson; 1990; Fishing News Books, Osney Mead, Oxford, England; 272 pp. - £30.00.

Water Law: Second Edition by William Goldfarb; 1988; Lewis Publishers, Chelsea, MI; 300 pp. - $58.00.

REFERENCE

Man in the Sea: Vol. I and II, an international effort in diving research compiled from the Second International Symposium of Man in the Sea; 1991; Best Publishing Co., Flagstaff, AR; Vol. I, 329 pp.- $32.00; Vol. II, 231 pp.- $30.00.

Out of Print and Rare Periodicals, Books and Expeditions on Marine Sciences compiled and published by Dieter Schierenberg BV, Amsterdam, The Netherlands; 1991; 103 pp. - free.

A World List of Mammalian Species, third edition by G.B. Corbet and J.E. Hill; 1991; Natural History Museum Publications, London, England; 243 pp. - $72.00.

THE POLES

Antarctica: An Introductory Guide by Diana Galimberti; 1991; Zagier & Urruty Publications, Miami Beach, FL; 157 pp. - $19.95.

The Explorations of Antarctica: the Last Unspoilt Continent by G.E. Fogg and David Smith; 1990; Cassell, London, England; 224 pp. - $24.95.

The Soviet Maritime Arctic by Capt. Lawson Brigham; 1991; Naval Institute Press, Annapolis, MD; 336 pp. - $34.95.

YOUNG PEOPLE

Adventures into Science (an educational video program including 12 video lessons on six 50-min. VHS tapes), 1990; Early Advantage, Norwalk, CT - $161.70.

Alligators to Zooplankton: a Dictionary of Water Babies (ages 10 and up) by Dr. Les Kaufman and staff of the New England Aquarium; 1991; Franklin Watts, Inc., New York, NY; 56 pp. - $14.95.

Do Fishes Get Thirsty? Questions Answered (ages 10 and up) by The New England Aquarium; 1991; Franklin Watts, Inc. New York, NY; 40 pp. - $13.95.

Ellisella the Coral, a True Story (Ages 3 to 10) written by Katherine Muzik, illustrated by Makoto Wada; Katherine Muzik, Boston, MA; 40 pp. - $10.00.

Follow the Water from Brook to Ocean (ages 5 to 9) written and illustrated by Arthur Dorros; 1991; HarperCollins Publishers, New York, NY; 32 pp. - $13.95.

Pomona: the Birth of a Penguin (ages 7 and up) by Catherine Paladino; Franklin Watts, Inc., New York, NY; 32 pp. - $12.95.

Whales (Ages 5 to 8) by Seymour Simon; 1989; HarperCollins, New York, NY; 38 pp. - $14.95.

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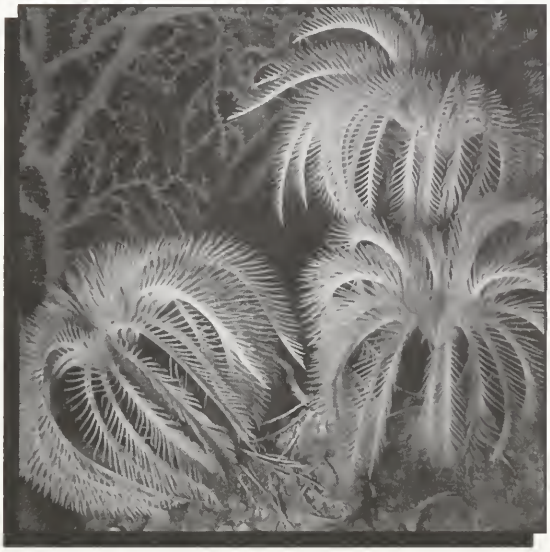
Reproductive Adaptations of Marine Organisms

Volume 34, Number 3, Fall 1991



Craig Young

Stalked Sea Lillies

The ocean is the largest—and perhaps oldest—habitat on Earth. Is it any surprise that it is also the most diverse? Here we will reflect on this diversity from a reproductive perspective. Are you an "r- selected" or a "k-selected" animal? What are the challenges of living 1,000 meters deep? What's good (or bad) about laying eggs? And, really, how DO jellyfish do it? This may be the raciest issue of *Oceanus* ever produced.

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Oceanography student sampling the nearby Indian River Lagoon.

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ABOVE: Human-powered submarine "Sea Panther"—an Ocean Engineering student project.

LEFT: Beach processes class after retrieving an electromagnetic current meter from the surf.

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